US Army Corps of Engineers
Construction Engineering Research Laboratory

DTIC ELECTE JUL 0 5 1991 S D C

USACERL Special Report N-91/15
June 1991

Management Tools for the 21st Century Environmental Office: The Role of Office Automation and Information Technology

by
John J. Fittipaldi
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Army environmental planning and compliance activities continue to grow in magnitude and complexity, straining the resources of installation environmental offices. New efficiencies must be found to meet the increasing demands of planning and compliance imperatives.

This study examined how office automation/information technology (OA/IT) may boost productivity in U.S. Army Training and Doctrine Command (TRADOC) installation environmental offices between now and the year 2000. A survey of four TRADOC installation environmental offices revealed that the workload often exceeds the capacity of staff. Computer literacy among personnel varies widely, limiting the benefits available from OA/IT now in use. Since environmental personnel are primarily gatherers and processors of information, better implementation of OA/IT could substantially improve work quality and productivity.

Advanced technologies expected to reach the consumer market during the 1990s will dramatically increase the potential productivity of environmental office personnel. Multitasking operating environments will allow simultaneous automation of communications, document processing, and engineering software. Increased processor power and parallel processing techniques will spur simplification of the user interface and greater software capabilities in general.

The authors conclude that full implementation of this report's OA/IT recommendations could double TRADOC environmental office productivity by the year 2000.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1991	Final

4. TITLE AND SUBTITLE

Management Tools for the 21st Century Environmental Office: The Role of Office Automation and Information Technology

5. FUNDING NUMBERS

IAO EFC9R130
dated 23 Nov 88

6. AUTHOR(S)

John J. Fittipaldi and Ben J. Sliwinski

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratory (USACERL)
2902 Newmark Drive, PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER

SR N-91/15

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Headquarters, TRADOC
ATTN: ATBO-GE
Fort Monroe, VA 23651

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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14. SUBJECT TERMS

TRADOC
office automation
information technology
environmental offices

15. NUMBER OF PAGES

74

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

EXECUTIVE SUMMARY

This study examined the potential impacts of office automation/information technology (OA/IT) on TRADOC installation environmental offices between now and the year 2000. Environmental office personnel at four TRADOC installations were surveyed to develop a profile of typical environmental office activities and to assess the degree to which OA/IT technologies are currently applied to environmental office functions. The survey of the four offices revealed the following:

1. The current environmental office workload has generally equalled or exceeded the capacity of the typical office staff.

2. The degree of computer literacy among personnel and the scope and effectiveness of OA/IT application in the office varies widely among TRADOC installation environmental offices.

3. Even offices with relatively high computer literacy and level of OA/IT implementation show signs of overloading, suggesting that the full benefits of OA/IT are not being realized an d that training in effective use of OA/IT is needed.

4. At the most fundamental level, the role of TRADOC environmental personnel is the gathering and processing of environmental information for presentation to various regulatory bodies and internal decisionmakers. For this reason, a strong potential exists for quality and productivity improvements through better implementation of OA/IT.

To project the potential impacts of OA/IT technologies on the office of the 21st Century, a comprehensive technology assessment of the OA/IT industry was performed. The scope of the assessment included examination of developments in microprocessors, communications and networking, peripherals and accessories, and software (including environmental engi. ering software packages). The results of the technology assessment indicated several trends with implications for the environmental office. In general, it was found that the performance of computer hardware in terms of speed and memory is increasing exponentially while costs are staying relatively constant, or even decreasing. Software developments, on the other hand, have been linear, so software capabilities lag behind hardware capabilities. There is little software available that fully uses existing hardware capabilities. Some specific technology developments, and their potential implications for the TRADOC environmental office, are as follows:

1. Advanced microprocessors and operating systems will provide a multitasking environment on personal computers, allowing simultaneous performance of many tasks by a single computer. This will allow TRADOC environmental office computers to simultaneously answer phones, transmit faxes, perform word processing, and run environmental engineering software.

2. The continued increases in processing speed and memory capacity and the trend toward desktop parallel processing are leading to software with powerful graphical interfaces. These interfaces will greatly enhance the ability of non-computer-literate personnel to use OA/IT effectively. These trends will also allow development of sophisticated environmental system simulation software.

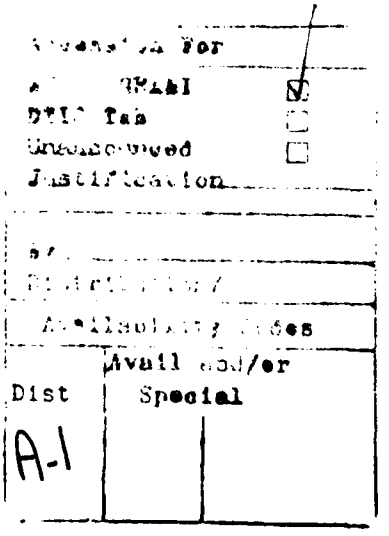
3. In the near future, advances in peripherals and accessories such as fax and voice mail cards, scanners, bar coding, digital video technologies, and specialized environmental and utility software will allow significant improvements in environmental office productivity at a relatively low cost.

The authors project that continued implementation of OA/IT will double TRADOC environmental office productivity between now and the year 2000. Recommendations for improving the effectiveness of OA/IT technology implementation include the following:

1. Develop TRADOC environmental office performance indicators to allow evaluation of the effectiveness of OAIT as it is implemented. These indicators will provide valuable feedback to TRADOC headquarters-level decisionmakers, resulting in informed direction of the technology implementation process. In addition, these performance indicators will provide information needed to justify the costs of the technology implementation program.

2. Develop effective means of disseminating lessons learned in OA/IT and the potential of new technologies. Examples include user groups, newsletters, and electronic bulletin boards.

3. Increase training in OA/IT technologies with emphasis on performance of specific TRADOC environmental office tasks. Training should concentrate on teaching usage of specific hardware, software, and methodologies as applied to such areas as polychlorinated biphenyl (PCB) transformers, asbestos abatement, radon, and underground storage tank programs.



FOREWORD

This project was conducted for Headquarters, U.S. Army Training and Doctrine Command (TRADOC), Fort Monroe, VA, under Intra-Army Order Number EFC9R130, dated 23 November 1988. The TRADOC technical monitor was Mr. Philip Prisco, ATBO-GE.

The work was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USACERL). John J. Fittipaldi was the USACERL Principal Investigator. Another contributor to the report was Ben J. Sliwinski, president of Research Associates, Inc., of Champaign, IL. Dr. Edward W. Novak is Acting Chief of EN.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Each Army installation within the Training and Doctrine Command (TRADOC) has an installation environmental office responsible for ensuring the installation's compliance with all applicable Federal, State, and local environmental regulations. These responsibilities are wide ranging and include activities as diverse as air and water pollution control, solid and hazardous waste management, forest management, and preservation of archeological sites. Also, because Army installations are distributed throughout the United States, the environmental conditions encountered, as expressed by climate and biosphere, vary from subtropical to arctic. The broad scope of the responsibilities of the Army environmental office results in a heavy workload; for this reason, many environmental offices have begun to integrate office automation/information technologies (OA/IT) into the performance of their duties. The incredibly rapid growth and development of these technologies in recent years, coupled with the Army's own efforts in developing software tools to use them, has resulted in the need to assess the potential inputs of these technologies on the operation of the Army environmental office through the year 2000.

Objective

The primary objective of the work presented in this report was to assess the impact of developments in information and office automation technology on the mission and performance of TRADOC environmental offices. A secondary objective was to outline how a 21st Century Army environmental office might be equipped with OA/IT technologies.

Approach

Current technical literature, trade publications, and conference proceedings were reviewed to evaluate trends in technology development. Experts at various organizations related to the OA/IT industry were contacted directly. The resulting assessment of the present and future state of the industry was integrated with an assessment of TRADOC environmental office needs and activities, which was developed though contacts with environmental offices at Fort Benjamin Harrison, IN, Fort Knox, KY, Fort Gordon, GA, and Fort Leonard Wood, MO, as well as TRADOC headquarters. The four installations were selected as representative examples of TRADOC installations with environmental office information needs. They are all located within a 1-day drive of USACERL, which the authors considered an important logistical advantage that facilitated visits to each site during that part of the research.

Nomenclature Used in Report

This report contains a number of terms and abbreviations in common usage in the OA/IT technology industry. These terms are defined in Table 1 so the reader may become familiar with them before starting to read the main body of this report.

Table 1

Common OA/IT Terms and Abbreviations

bit—binary digit; the basic unit of information processed by digital computers.

byte—a sequence of eight adjacent binary digits, processed by the computer as a unit.

CD-ROM—compact disk-read only memory (optical disk).

chip—short for microchip; the hardware unit upon which key circuitry is printed microscopically.

clock speed—the parameter for measuring microchip processing speed, usually in megahertz.

cps—characters per second (printer output speed).

CPU—central processing unit; a microcomputer's main chip.

DOS—see *MS-DOS*.

dpi—dots per inch (printer output resolution).

Ethernet—a widely used brand of networking software.

grayscale—a noncolor video display that can display any or all single points (pixels) in varying degrees of brightness to create high-resolution graphics on the screen.

GUI—graphical user interface; a philosophy of design that allows users to control a computer and its software through a system of easy-to-use menus and visual graphical elements; it shields the user from the complexities of the computer's operating system software.

hardware—the machinery used in computer operations (e.g., processors, monitors, printers).

I/O—input/output.

interleaving—a technique that accelerates the access of data from a hard disk by writing it to (and retrieving it from) nonadjacent disk sectors.

kB—kilobyte; 1000 bytes.

kbits—kilobits; 1000 bits.

LAN—local area network.

macro—a software technique for automating a computer to perform frequently repeated or repetitive tasks by executing a short keyboard command.

Table 1 (Cont'd)

MB—megabyte; 1,000,000 bytes.

Mbit—megabit; 1,000,000 bits.

MHz—megahertz; 1,000,000 Hertz (1 Hz equals one electromagnetic wave cycle per second).

modem—a piece of hardware that permits a computer to transmit and receive data over telephone lines.

module (software)—a distinct unit of software that is integrated as part of a larger application; often an add-on subprogram that enhances the operation of a larger one.

ms—millisecond; 1/1000 of a second.

MS-DOS—Microsoft Disk Operating System; the software controlling mainstream IBM-compatible personal computers; also called *DOS*.

node—a station on a LAN that can send and receive information.

OS/2—Operating System/2, a non-*DOS* advanced IBM disk operating system for personal computers.

parallel—the simultaneous execution of more than one computation or operation.

RAM—random access memory.

serial—the sequential execution of instructions or operations.

server—a computer that makes applications and/or data available to other computers to which it is connected as part of a network.

slot—an area in computer hardware designed to physically and electronically accommodate extra circuit boards and certain related devices (e.g., modem).

software—computer program, the component of computer systems that accomplishes specific tasks for the user.

VCR—videocassette recorder.

VHS—video home system; a hardware and software format for recording and playing back videotape.

WORM—write once read many data storage (optical disk).

2 HARDWARE DEVELOPMENTS

Processors

Few developments have affected the office environment more than the introduction of the microcomputer. This device, and the revolutionary capabilities it gives its users, have been a source of both solutions and confusion for most organizations.

Developments in microcomputer hardware have been rapid since their introduction. In fact, hardware is evolving so rapidly that the state of the art, as described here, will certainly change before this report is published. Therefore, it is advisable to limit this discussion to the better mainstream technology that is readily available and moderately priced, not the latest "cutting edge" equipment. Currently, this category of hardware includes 32-bit Intel 80386-based machines and Motorola 32-bit 68030-based machines. The 80386 processor is used in IBM, Compaq, and IBM-compatible machines, as well as certain Sun workstations. The 68030 central processing unit (CPU) is used in Apple Macintosh, Commodore, and NeXT machines and in many vendors' workstations. Of course, many microcomputers using the earlier 8086, 8088, 80286, 68000, and 68020 processors are still available, and these machines will continue to make up a significant portion of the market.*

At this time, 80386 machines are available having clock speeds as fast as 33 megahertz (MHz); 68030 machines are available at 25 MHz, but Motorola has recently announced a 50 MHz version of the same chip. Figure 1 illustrates the growth in CPU clock speeds over the last several years. Clock speeds, however, are only part of the overall machine speed equation; factors such as the speed of its random access memory (RAM) chips and disk input/output (I/O) must also be considered. For this reason, other measures of overall computer system speed, such as MIPS (millions of instructions per second) and MFLOPS (millions of floating point operations per second), are also used. For example, most high-performance microcomputers now use a memory cache, which holds recently used information in RAM, where it may be accessed again more quickly than from the disk. Cache memory can greatly enhance a machine's performance. During normal operation, the information the computer needs next can be found in cache memory 80 percent of the time.[1] In one test of 16 MHz 80386-based machines, the machine with cache memory performed floating point operations (multiplication, division, exponentiation, and logarithmic and trigonometric functions) 12 percent faster than a similar machine without cache memory.[2] Trends in machine performance (in MIPS) are shown in Figure 2.

One system currently available that incorporates many trend-setting characteristics is the NeXT computer. This unit consists of a 25 MHz 68030 CPU with 8 megabytes (MB) of RAM and a 68882 math coprocessor. The system can be configured with a 670 MB magnetic disk—a medium for semipermanent data storage—and an erasable optical/magnetic disk drive supporting 256 MB laser-read optical disks. The system includes a built-in digital signal processing unit (Motorola DSP560001) that makes it useful for real-time laboratory work. Also included is a 17-in. monochrome monitor and a 400 dots-per-inch (dpi) laser printer.** The NeXT machine uses a proprietary version of the *UNIX* operating

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*This report necessarily makes frequent references to various commercial hardware and software product names and brand names. All product names and brand names are trademarks or registered trademarks of their respective holders.

[1]B. Brown and S.K. Losee, "The Midrange Has Moved: 386s Become Affordable," *PC Magazine* (28 February 1989), p 170.

[2]B. Brown and S.K. Losee, p 154.

**17 in. = 43.18 cm; 1 in. = 2.54 cm.

system that presents a user-friendly graphical user interface (GUI) instead of the standard, complicated *UNIX* command line interface.

This hardware and operating system software allow the NeXT machine to be a true multitasking computer—one that can run different programs simultaneously. (There are also multitasking systems based on other processors and operating systems.) Multitasking capability makes a computer user much more potentially productive, and will have a strong impact on the way users approach their work. For example, an engineer using a multitasking system could run a time-consuming application (such as data analysis or a simulation) in the background while simultaneously word processing a report.

Multitasking allows several applications (or users) to share a microprocessor. Also becoming available are multiprocessor systems like the Zenith Z-1000, which uses up to five processors. This multiprocessor configuration allows each individual processor to simultaneously perform different applications, and potentially to operate as a limited parallel processor.

Several important new CPU chips will begin appearing as midrange hardware in the next 5 years. These processors, introduced by Motorola and Intel, could triple the performance of IBM-compatible, Macintosh, and *UNIX*-based workstations.

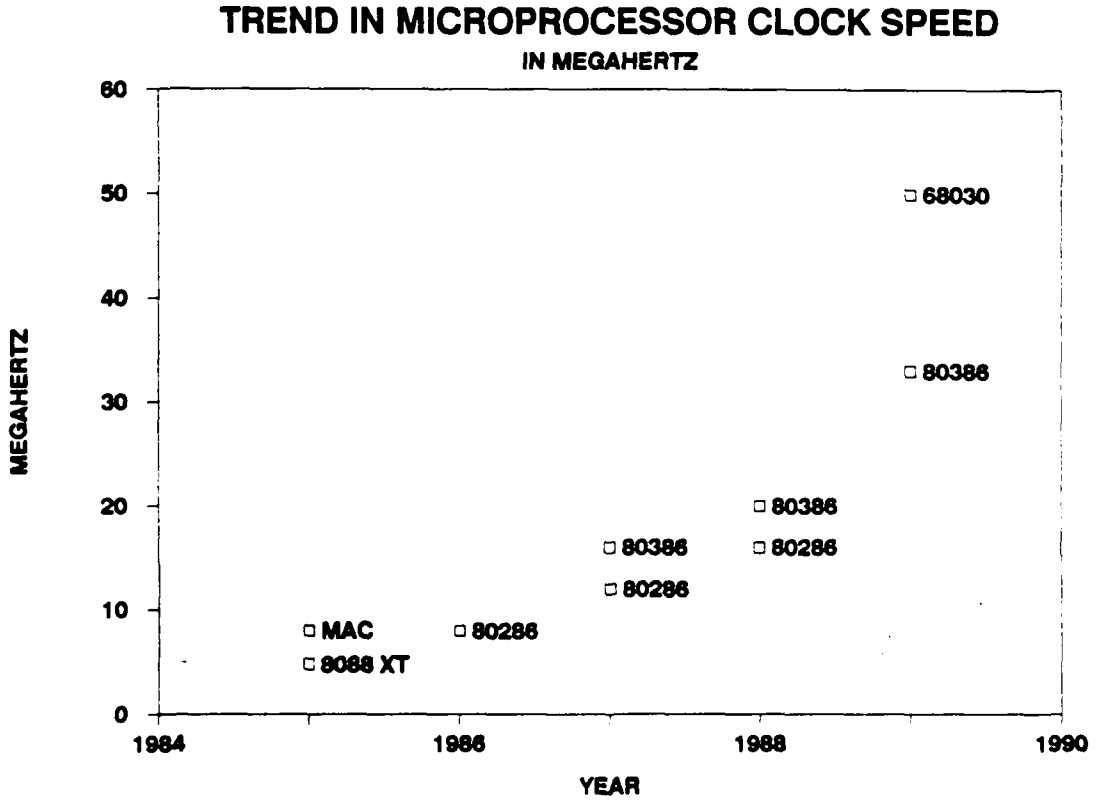

Figure 1. Microprocessor clock speed trends.

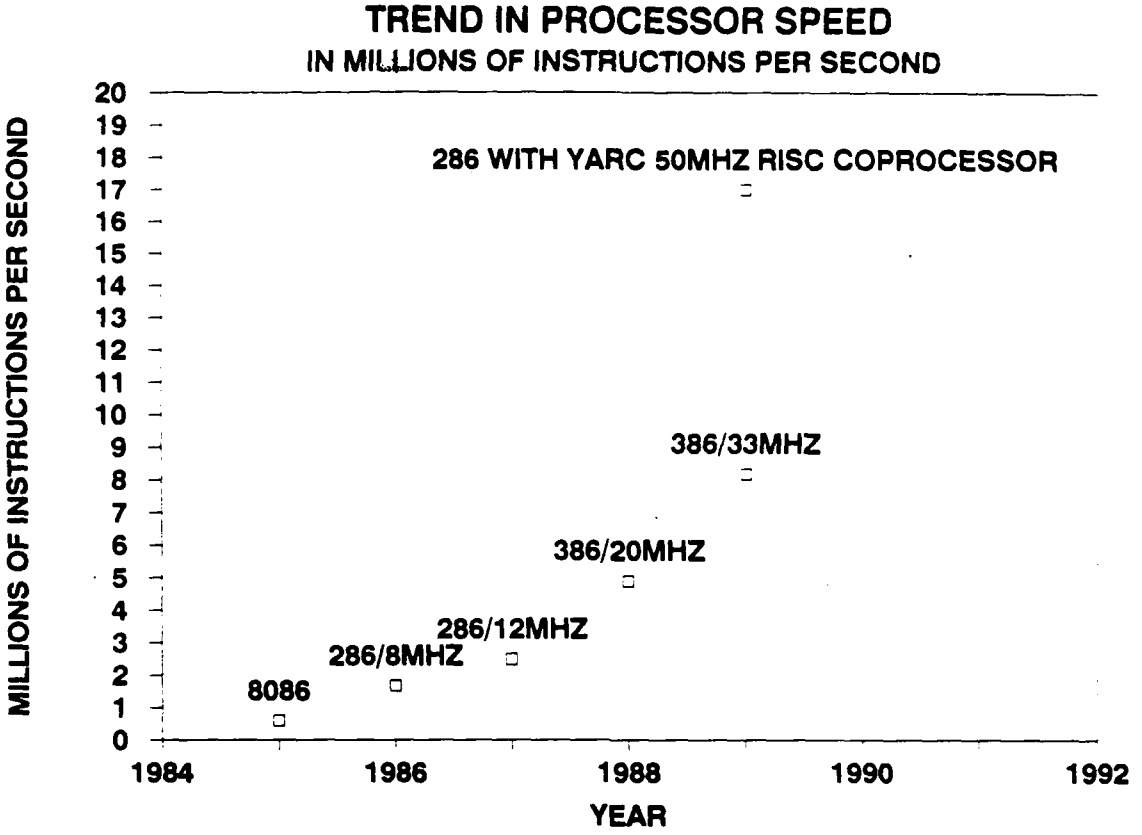

Figure 2. ***Microprocessor speed trends (in MIPS).***

The first of these, the 80486 processor from Intel, is expected to be two to four times faster than the 80386. The 80486 performs several functions that today are performed by separate chips. It combines an enhanced 80386, an enhanced 80387, a memory management unit, a cache controller, and an 8 kilobyte (kB) cache. The 80486 has the potential to be used in parallel processing applications, a method of computing that divides highly complex problems into several less complex ones, each of which can be processed simultaneously for greater speed. The 80486 running at the same clock speed as an 80386 is three times as fast. Early 25 MHz and 33 MHz versions of the chip operate at 15 to 20 MIPS. Intel expects to see 80486 machines replacing the 80386 in high-performance file servers and in multiprocessor systems. A 33 MHz version was scheduled for the end of 1989, with a 40 MHz version expected in 1990 and a 50-60 MHz version planned for 1992. IBM has hinted that an 80486-based PS-2 may be available in early 1990. Also, a British company has introduced an 80486 machine that works at 15 MIPs and comes with a 5-gigabyte (5 billion byte) hard drive.

The second new-generation microchip is the Motorola 68040. Like the 80486, it combines the CPU, math co-processor, and cache memory on a single chip.

RISC Processors

Reduced Instruction Set Computing (RISC) refers to a CPU that executes at least one instruction per clock cycle. By contrast, today's standard personal computers are CISC (Complex Instruction Set

Computing) machines, which can take several clock cycles to execute a single instruction. By paring down the complexity of a CPU's instruction set, RISC processors can execute more instructions in the same time. Through an additional technique called pipelining, RISC processors can actually execute several instructions at a time—some as many as five instructions simultaneously. Present RISC CPUs operate at clock speeds of 16 to 25 MHz, produce 10 to 20 MIPS, and are used widely in engineering workstations. One of the most advanced RISC chips, the Intel 80860, has been called a "supercomputer on a chip." It is a 64-bit processor that contains 1 million transistors and runs at 40 to 50 MHz. Under ideal conditions, the chip can perform three operations simultaneously, potentially producing 120 MIPS. One major application for this chip is graphics: to draw pictures on a video display, a computer needs to perform a vast number of floating point calculations, at which the 80860 excels. IBM and Intel have demonstrated an 80860 personal computer configuration that can probably out perform most workstations.

The concept of one CPU performing multiple operations simultaneously is further extended in VLIW (very long instruction word) computers, predicted by some experts as the successor to RISC. Some VLIW processors can perform seven operations simultaneously.

Parallel Processing

As previously stated, parallel processing uses multiple processors simultaneously to perform a highly complex calculation or task. Parallel processing is central to supercomputing, but there are now indications that this powerful technique may be applied to desktop microcomputers. The first working parallel processor system was the ILLIAC IV, developed at the University of Illinois in 1966. It consisted of 64 processors. The first commercial parallel processor, developed by Denelcor in 1985 was not a market success, but by 1986 more than a dozen companies were selling parallel processors. Today, parallel processing systems such as the Connection Machine from Thinking Machines can execute billions of operations per second using up to 65,536 processors simultaneously. Searching an 18-MB database using a 16,384-element Connection Machine takes about 0.004 seconds.

The central problem of parallel processing is determining how to most effectively use the processors. Only certain kinds of problems have a structure that is appropriate for the parallel processing approach. These include simulations, modeling, optimization, and database searches. In fact, using parallel processors to search large commercial databases is becoming an important commercial use of supercomputers.

The key to successfully using parallel processing techniques is an effective parallel processing programming language. According to David Galertner of Yale University, parallel programming languages can be placed in three categories: Algol-based languages like Ada and Linda; parallel LISPS and logic languages like Multilisp and Concurrent Prolog; and parallel functional languages like Parafl.[3]

An important distinction among parallel processors is whether they are multiprocessors or multicomputers. A multiprocessor comprises a collection of processors connected by a common bus, or electronic circuit. Because of the bottlenecks that result from excessive signal "traffic" on the bus, this configuration seldom uses more than four processors. In a multicomputer, however, the processors are not connected to a common bus. Instead, each processor has a dedicated RAM (64 kB to 4 MB) through which it is connected to a local bus. The processor and the RAM together are called a node; communication between nodes takes place through high-speed serial links. The T800 transputer,

[3]Klaus K. Obermeier, "Side by Side," *Byte* (November 1988), p 275.

developed by INMOS, is a multicomputer building block. Each transputer consists of a processor, 4 MB of RAM, and four high-speed serial ports. The serial ports allow the T800 to communicate at a rate of 120 mbits/sec, moving 12 times as much data per second as an Ethernet link. The T800 costs around $1000 (1988), operates at 30 MHz, and delivers 15 MIPS.

Cogent Research, in Beaverton, Oregon, has developed the Cogent XTM, a desktop supercomputer based on the T800 transputer. The architecture of the XTM is like a combination of a multiprocessor and a multicomputer. A problem does not arise because of data bottlenecking at a common bus, as with multiprocessors, but rather because of the large number of connections required among all the nodes. For example, a fully connected network of 1000 processors would require 499,500 connections. Some fixed-network systems work around this problem by connecting each processor only to its nearest neighbors, but then data must often be passed from processor to processor, slowing the system down. The XTM surmounts these difficulties by using a hybrid communication architecture that has both a common bus and a unique serial communications network.

In the XTM, the transputers all share an ordinary parallel communications bus. Separately, the four serial communications channels of each transputer are connected to an intelligent switching system. Upon request, the intelligent switch can directly connect any two transputers in the network. Consequently, any two transputers can communicate either through the shared bus or a temporary "private" connection. The XTM's intelligent switch can link any two transputers in 40 ms and can reconfigure the entire computer in 200 to 400 ms. Using this system, 1000 processors can communicate using only 4000 serial lines, less than 1 percent of the number required for a fully connected network. The simplest desktop XTM starts with two processors in a cabinet a little smaller than an IBM PC. The system, with a 90 MB hard drive and monochrome monitor, costs $19,800. To add processors requires a resource server consisting of 16 slots, the intelligent switch, and a communications card to connect to the XTM. The workstation, resource server, and disk servers all communicate through a fiber optic cable at 100 megabits (Mbits) per second. A workstation equipped with one server fully packed with processors is compact enough to fit on a desktop and costs $200,000. Cogent has developed a system for Sandia National Laboratory, NM, consisting of 1900 processors, and approaches the power of a Cray X-MP supercomputer. An interesting point is that the two-processor machine and the 1900-processor machine both use exactly the same hardware.

Obviously, the cost of each processor and the required communications among them cost much more than a midrange desktop microcomputer. Using a special programming language, however, it is possible to configure a network of individual computers to work as a multi-site parallel processor. This has actually been accomplished on a VAX/VMS local area network (LAN). Running the language Linda on 14 VAXes, some in California and some in New Mexico, researchers have created a virtual super-computer.[4] The machine worked on off-peak VAX cycles no one else was using. Similar feats may be possible by networking microcomputers, allowing organizations with dozens (or hundreds) of these units to use them as a parallel processing supercomputer during off hours.

Neural Networks

A neural network is a data processing system consisting of a number of simple, highly interconnected processing elements designed to imitate the architecture of the brain. Neural networks can be implemented in hardware and, to some extent, in software. Neural networks are not programmed in

[4]David Gelertner, "Getting The Job Done," *Byte* (November 1988), p 301.

the conventional way, but are "taught" to figure out the most appropriate answers to questions not answerable with reliability by conventional computing technology. One neural network developed in the past is used today in high-speed modems to perform adaptive signal processing and other functions. Although the technology is still considered to be in its infancy, one early version of a neural network was used in 1963 as a weather forecasting system, and reportedly had an 83 percent rate of accuracy.[5]

Neural network technology is sometimes referred to as "connectionism." In this kind of system, data is entered along with weighting values for use by the connections that make up the network architecture. The network is then operated repeatedly (while it "considers" the weights of the various connections) until a satisfactory answer is obtained. The resulting weighted matrix of interconnections actually represents the system's "learned" response to user input and allows the network to remember and learn more. Neural networks can potentially take incomplete data and produce a reliable "educated guess," a capability not currently available in mainstream microcomputer technology. Their parallelism, speed, and "trainability" make them fault tolerant, as well as fast and efficient for handling large amounts of data.[6]

Neural networks are being produced and used in two basic forms: neurocomputers (hardware that models the parallelism of brain neurons) and netware (software that emulates neurons and their interconnections). An important aspect of netware is that it can run on conventional microcomputers. Neurocomputers are available now as chips, boards, and complete systems. NEC has announced the development of a neural network personal computer, which it plans to market in Japan as the Neuro-07.

Neural network applications are currently available in the areas of sensor data and knowledge processing, pattern recognition, and control systems. There are indications that the power of neural networks may supersede many currently available expert systems and artificial intelligence (AI) technologies. For example, a neural net program called *NetTalk* can learn to read English text aloud without any preprogrammed linguistic rules. However, conventional expert systems and artificial intelligence technologies have difficulty executing this function.[7]

Because neural network technology is still young, large-scale applications by TRADOC environmental offices will probably not occur within the next 5 years. In the long term, however, it is likely that software developers will begin to apply neural network technology to environmental engineering. The decision support area in particular could benefit by taking advantage of the neural network's ability to process "fuzzy" or incomplete data. The appendix lists several neural network hardware and software products.

Memory

RAM Chips

The trend in computer memory has followed the trend in processor hardware. Memory is getting larger, faster, and cheaper per unit. In 1982, a RAM expansion board cost about $4.00 per kB; today, the cost is closer to $0.90 per kB. Many IBM-compatible and Macintosh systems today come with 1 MB of RAM while the original IBM-PC came with only 16 kB. Memory sizes have increased to keep pace with software demands and the ability of operating systems to use larger amounts of memory. The original

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[5]Klaus K. Obermeier and Janet J. Barron, "Neural Networks—Time To Get Fired Up," *Byte* (August 1989), p 217.
[6]Klaus K. Obermeier and Janet J. Barron, p 220.
[7]Klaus K. Obermier and Janet J. Barron, p 220.

upper limit of MS-DOS—640 kB—can now be surpassed by using special software. In addition, as IBM's *OS/2* operating system becomes more prevalent, RAM sizes should increase up to 16 MB.

Magnetic Disks and Tape

Similar cost trends are occurring in magnetic disk memory. Figure 3 illustrates the trend (in dollars per MB) for hard disk units from 1985 to 1989. The decreasing cost per megabyte of storage and the increasing demand by advanced programs for more disk storage are leading to the introduction of larger hard disks into the typical desktop microcomputer. Today, for example, $500 invested in a hard disk can deliver about 65 MB in disk storage, depending on manufacturer and model.

The data-access speed of hard disks has also increased to keep pace with the higher speeds of processors. Slow drives—40 milliseconds (ms) or slower—can work substantially faster using a technique called interleaving. A slow 40-MB disk, for example, can be divided into two 20-MB partitions; the CPU sends information to one partition at a time, allowing one to process data while the other receives data. Without interleaving, high-performance disk drives now offer 28 ms performance, and drives using ESDI (Enhanced Small Device Interface) controllers provide 16 ms performance. The biggest difference between ESDI controllers and the standard ST-506 controller used by most earlier IBM-compatible hard disks is that the ESDI moves data at 10 MHz—twice as fast as the ST-506. The ESDI technique also packs twice as much data onto each disk. The ESDI interface is most often used by large drives with capacities in excess of 100 MB.

Magnetic tape drives continue to be an important storage medium. For microcomputers, tape drives are very useful for hard disk backup. One interesting product in this area converts a standard VHS video recorder to be used for backup. A standard VHS cassette can hold 80 MB of data. For an organization that already has a VCR, this option leads to a significant savings.

Optical Disks

Up to this point only magnetic disks have been discussed here, but optical memory technologies are now available and developing rapidly. CD-ROMs, WORM (write once, read many) drives, and even erasable optical disks offer very high data storage densities. Capacities range from 250 MB to 800 MB per disk, and they are as portable as floppy disks.

Presently, erasable optical disks are slower than magnetic disks (100 to 40 ms, compared with 60 to 16 ms), but their speed is expected to increase. The greatest advantage of optical systems is their higher data storage density. The upper limit for magnetic storage appears to be in the range of 100 megabits (Mbits) per square inch, while the limit for optical systems appears to be 30 times greater.[8] Furthermore, the portability of these disks and their resistance to data loss caused by magnetic fields offer additional competitive advantages over magnetic media. However, it seems likely that magnetic systems will continue to be a viable storage medium into the foreseeable future.

[8]Robert P. Freese, "Optical Disks Become Erasable," *IEEE Spectrum* (Institute of Electrical and Electronics Engineers [IEEE], February 1988), p 41.

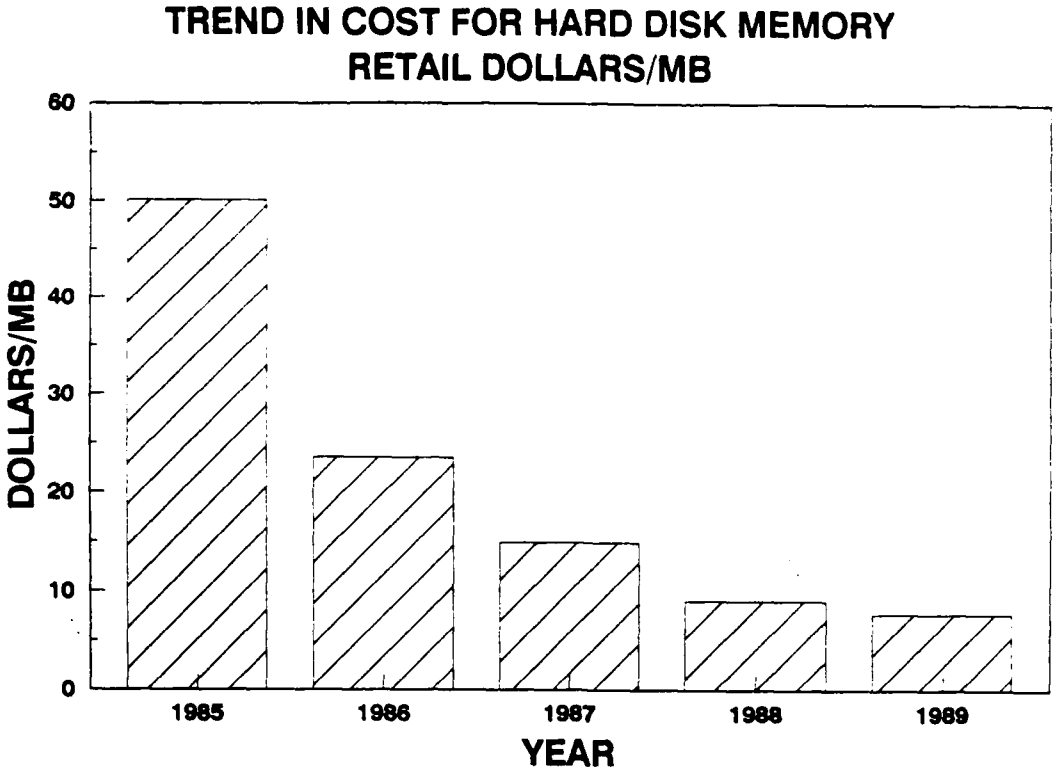

Figure 3. Hard disk cost trends.

Input Devices

Several recent advances in data input technology could potentially improve productivity in environmental offices. These include bar code printers and readers, image and text scanners, touch-sensitive video displays, and I/O cards to allow PCs to function as data acquisition systems.

Bar Code

Bar code systems are now available with menu-driven programs to allow user-friendly label design, and can merge data for the labels directly from disk files. These programs can print the bar codes on dot matrix, thermal transfer, and laser printers. Systems are even available that allow the printing and reading of bar code labels in the field. Readers are available for all the major IBM-compatible and Macintosh systems. Potential applications for environmental office usage would include labelling and tracking of transformers containing polychlorinated biphenyls (PCBs), hazardous wastes, and hazardous materials.

Image and Text Scanners

Image and text scanners are possibly the most important recent productivity development in data input systems. These devices convert analog pictures and text into digital data for easy computer input. Scanners are available as both hand-held and desktop devices. Hand-held scanners can digitize an image about half the width of a standard letter-size page (10 cm x 28 cm) while desktop units can scan images up to ledger size format (28 cm x 43 cm). Resolution is typically 300 dpi, but some go as high as 900

dpi. There are scanners available for black and white, grayscale, and color images capabilities. Storing scanned images can require a lot of disk memory: a 6 cm x 7.5 cm color image scanned at 300 dpi can require 2.3 MB of disk space.

Scanners can digitize images from color slides and transparencies, and some can even scan 3-dimensional objects. A development making scanners a particularly powerful tool, however, is the improvement of optical character recognition (OCR) software. This software uses AI to help a scanner to recognize text in a wide variety of typefaces and styles. Lately OCR software has greatly improved in its accuracy. It is also much less sensitive to flaws such as smudges or dirt specks on the original document. There is now software that can differentiate between text, graphics, headlines, and multiple columns in one pass. The scanner software is capable of producing digital information in a format compatible with most word processing, page layout, and spreadsheet programs. The scanning rate for text is about one page per minute. Efforts to speed up the scanning process are turning to hardware-based OCR. One system, using four Motorola 68000 processors, can scan and recognize the text in a formatted letter-size page in less than 15 seconds. Coupled with a fax board, a laser printer, and a scanner, a desktop computer can function as a complete fax and copying machine.

Voice Input

Voice input technology for data and system commands is slowly emerging. There are currently a few commercial systems available, aimed primarily at marketing applications. One system, designed for telemarketing, can respond to the words yes and no, and can recognize the numbers 0 through 9. Another system can recognize 16 words. A number of products are becoming available that provide limited voice recognition capabilities for microcomputers. One system, the Voice Master Key System by COVOX, Inc., actually recognizes spoken software commands, bypassing keyboard input for programs such as *Lotus 1-2-3*, *Multimate Advantage*, and *WordPerfect*.

Data Acquisition and Control

There are currently many add-in boards, available for most standard personal computers, which allow direct input from almost any data acquisition device. They can perform a range of useful tasks, including acquisition and storage of data from laboratory instruments or weather stations to control of pumps, motors, fans, etc. Combined with a laptop computer and a cellular telephone and modem, it is possible to quickly configure a relatively inexpensive, sophisticated, remote data acquisition system. Many data acquisition programs have built-in compatibility with many common data acquisition devices, and are very user friendly. Also, many of these software packages include powerful data analysis and presentation capabilities.

Other

Two other input devices are worth mentioning. One is the standard nine-track tape drive: these are certainly not new, but a number of vendors now offer them specifically designed to interface with microcomputers. These systems offer an effective way for micros to share large quantities of data with mainframes and minicomputers.

The other device, the touch screen, can be useful in training situations, process control, and simulations. Generally, touch screens are used when extensive data entry is not required. Touch screens are available to fit over most types of video displays and generally are designed so the user does not

realize that one is in place. Input is received by touching the screen at indicated locations. Most screens include software for appropriate video display generation and interfacing with application programs.

Output Devices

Printers/Plotters

The wide variety of printers available for microcomputers can be divided into several major categories, depending on their print mechanisms. The most common are dot matrix, thermal, daisy wheel, ink jet, and laser. The laser printer currently represents the most advanced office printer technology in terms of combining high quality with high speed. Standard office laser printers typically print text and graphics at 6 to 12 pages per minute. Dot matrix printers sacrifice some quality but are almost as fast as laser machines. However, dot matrix printers are now available with 24- and 27-pin print heads and offer reasonably good letter quality—even color output—at moderate prices. The dot matrix is probably still the most common office printer. They perform at draft speeds ranging from 180 to 450 characters per second (cps) and near letter quality speeds of of 30 to 120 cps. One current model prints at 850 cps in draft mode. Daisy wheel printers are slow (20 to 40 cps), but still find a place in offices where high quality text is desired at a low price, and graphics capabilities are not necessary. Ink jet printers offer quality somewhere between 24-pin dot matrix and laser printers. They are slower than laser printers but less expensive.

All of these technologies are expected to improve incrementally over time.

Plotter technology is very well established, and there are many different types available for microcomputers. Plotters vary in size from small desktop units to 1 m x 1.3 m or more (for engineering and architectural drawing). Most plotters offer color output through interchangeable pens. They range in speed from 5 cm to 25 cm per second.

Multimedia Hardware

A number of powerful technologies are emerging that enable microcomputers to produce visually sophisticated multimedia presentations. These technologies allow microcomputers to produce overhead projector transparencies and 35 mm slides, project video displays from the computer to an external screen, digitize and edit video images, produce videotape titles and special effects, and produce fully animated video displays.

For generating 35 mm slides there are many products available. The Polaroid Palette was one of the first affordable analog film recorders for making slides from computer displays, and is today the only popular such recorder in the business market. Most of the other systems now use digital technology.

Digital recorders work well for business applications because they can produce professional looking, high quality slides. They usually require adapter cards and software drivers to work with graphics programs. Two popular digital film recorders are the Montage FR1 from Presentation Technologies, and the Matrix ProColor from Matrix Instruments, Inc.

High quality overhead projector transparencies can be easily made with a laser printer. Another technology allows projection of computer screen displays by using a transparent liquid crystal display

(LCD) on an overhead projector in place of the conventional transparency. Hardware for generating and displaying computer-based slide shows (stored on magnetic disk) is available in the form of VideoShow, from General Parametrics Corp. VideoShow hardware comes with a wireless remote unit for controlling the disk drive and signal generation device. The system can project "slides" through either a color monitor or a large screen video projector.

At the frontiers of multimedia technology are systems that integrate video images with computer displays. Presently, four levels of sophisticated technology are used to interface video and microcomputers: frame grabbers, genlocking of video and computer graphics, interactive use of video stored on CD-ROM (compact disk-read only memory) or magnetic disk, and interactive real-time creation, storage, editing, and transmission of video data.

Frame grabbers are plug-in cards that capture the information in a frame of video (usually from a television, video recorder, or camera) and convert it into a digitized image. The image can then be stored, edited, used with a word processor, and printed just like other digital graphics.

Genlocking is the synchronization of standard television video signals with computer-generated graphics signals. A common application of genlocking is the creation of titles and special effects used on television. The resulting mix of computer graphics and video images can be stored on videotape for later playback.

Interactive use of video data on a CD-ROM or hard disk requires that video signals be digitized and compressed for computer compatibility and efficient disk storage. Digitization and compression is a slow process, so real-time video is difficult. Stored and compressed images can be replayed, however, in full motion. This technology is currently finding use in education, training systems, and point-of-sale applications.

Technology for interactive real-time creation, storage, and editing of digital video data is under development. Some aspects of this technology can be achieved through compromises in frame rate, picture size, and image quality.

Communications Hardware

Local Area Networks

LANs, or local area networks, are systems that use hardware and software to link several computers (sometimes hundreds) so they can share information and resources. They provide services such as electronic mail, and allow the sharing of printers, fax machines, software, extended disk storage, and communication ports to other networks. The speed at which a LAN transmits data is a basic element of system performance, and may vary from several hundred kilobits (kbits) to 10 Mbits per second. It is predicted that transmittal speed may soon reach as high as 100 Mbits per second. These high-performance systems will be driven by fiber optic communications technology, known as fiber distributed data interchange (FDDI) networks. This type of equipment currently costs about $5000/node (compared to $600/node for current coaxial technology), but prices are expected to drop.

The hardware typically consists of a LAN card—one for each microcomputer in the network—and cables that link the system. There are two categories of hardware: active and passive. In active network systems (e.g., the token ring configuration) every station is involved in the passing of data. In effect,

messages are passed in a ring. Passive networks (e.g., Ethernet), however, involve only the sending and receiving stations in the sending of messages. Ethernet operates at 1 or 10 Mbits per second. A token ring system operates at 4 and 10 Mbits per second, but will soon reach 16 Mbits per second. The difference in architecture between active and passive systems makes simple speed comparisons difficult.

Software-based LANs are also available. These networks do not require a LAN card but, instead, use the microcomputer's parallel or serial port. Since these systems do not require the add-on LAN card, they are less expensive and can be easier to set up. They are slower than a hardware-based LAN, however, with speeds in the range of 0.5 Mbits per second.

While LANs are revolutionizing many office settings, they are not as important to the installation environmental office at this time. EN office functions do not generally require large numbers of people to have access to the same information.

Fax Boards

Fax machines are now considered an office necessity. There are now fax boards available that allow the microcomputer to function as a fax machine, and they generally cost less than an inexpensive fax. Some of these boards offer features found only on the most expensive fax machines, and messages sent from fax boards frequently look better than messages sent from conventional machines. Fax boards are compatible with most dot-matrix and laser printers, which provides the advantages of plain paper printing (instead of using the flimsy thermal paper that conventional fax machines print to). Fax boards are also compatible with scanners, but normally they send text or graphics files from the word processor or graphics software. The fax boards operate while other applications are working and provide features such as scheduled transmission, broadcast to multiple recipients, and automatic redial. Some systems are compatible with LANs and allow electronic mail (e-mail) messages to be converted to a form that can be transmitted via fax.

Voice Mail

Voice mail is available as an on-line service, but is also available as an add-on card for microcomputers. Voice mail systems interface with the user's telephone and take messages, deliver messages, and even transfer calls. Users who are away from the office can call their voice mail system to get their messages. The voice mail card converts voice messages into digital form and records them on the microcomputer's hard disk. It provides individual private "mailboxes," each coded by password. Some systems support as many as 999 mailboxes. When calling someone who is not in, the user leaves a password with the receptionist (or a voice mail system); that person returns the call and uses the password to get the message without disturbing the person who sent the message. Since voice mail systems work in the background, the user can work on the computer while the voice mail card sends and receives messages. Several vendors are listed in the appendix.

Integrated Services Digital Network (ISDN) Systems

The term Integrated Services Digital Network (ISDN) came into use in the late 1970s and indicates the direction of digital telecommunication systems. ISDN is defined as "a network, in general evolving from a telephony IDN, that provides end-to-end digital connectivity to support a wide range of services,

including voice and nonvoice services, to which users have access by a limited set of standard multi-purpose user-network interfaces."[9]

In the near term, ISDN services are expected to use existing telephone hardware (i.e., standard copper wires). The types of services that potentially can be provided include computer communications, voice signals, video signals, remote reading of utility meters, and remote control of building functions such as heating and air conditioning. The essential point is that while only one pair of wires connects the user's terminal to the network, several ISDN services may work simultaneously. The user may speak on the telephone while using the computer to transmit and receive data, and while a utility company uses the same line to read the user's power meter. Two forms of ISDN access are currently envisioned: basic access, known as 2B+D, which consists of two B channels and one D channel; and primary access, known as 23B+D, which consists of 23 B channels and one D channel. Each B channel is capable of carrying voice or data at 64 kbits/sec. The D channels carry 16 or 64 kbits/sec and are available for data and signalling only. The total capacity of the basic ISDN access is 144 kbits/sec; for primary access the capacity is 1544 kbits/sec. By comparison, a high-speed modem transfers data over the analog phone network at speeds of around 9.6 kbits/sec.

The superior speed and ability to provide simultaneous access to many services are driving forces toward ISDN implementation. There are forces, however, that have somewhat slowed the acceptance of this technology. First, the inertia inherent in the large established telephone systems; while ISDN can use existing lines, there are still significant capital investments required to provide these services. Second, while the present narrowband ISDN services can be provided over existing copper wires, these wires cannot support the necessary bandwidth for full-motion video or high-speed data transfer. These advanced services would require broadband ISDN with data rates as high as 622 Mbits/sec.[10] The minimum requirement for a broadband system is a network of coaxial cable, and ultimately, fiber optic cable. Again, development is inhibited partially due to the required capital investments, but also because the potential of broadband ISDN may induce some potential users to take a "wait and see" attitude. Third, ISDN has been a technology without a clear target market. Customer need for ISDN services has not been clearly established nor has its cost effectiveness been demonstrated. Customers commonly ask, "Why should I subscribe to an ISDN capability when I can already achieve an integrated facility using separate voice, data, and video networks which are cost effective for my immediate operations?"[11]

The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), has taken a lead role in fostering the development and acceptance of ISDN technology. The North American ISDN Users' Forum (NIU-Forum) was formed under NIST sponsorship in February 1988 to help ensure that emerging ISDN technology meets users' needs. The two principal segments of the NIU-FORUM are the ISDN Users' Workshop (IUW) and the ISDN Implementors' Workshop (IIW). In addition to the NIU-Forum, NIST sponsors the NIST Workshop for Implementation of Open System Interconnection (OSI). Among its many activities, the NIU-Forum, in cooperation with the U.S. Navy, operates a bulletin board service, the NIU-BBS. The NIU-BBS is designed to support the efficient functioning of the NIU-Forum and to facilitate the exchange of timely, accurate, and useful information about ISDN among users, vendors, service providers, standards communities, and other interested parties.

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[9]John Ronayne, *The Integrated Services Digital Network: From Concept to Application* (John Wiley and Sons, New York, 1988).

[10]George D. Kraft and Thomas R. DeWitt, "Methods for Achieving a Standard, Compatible and Interoperable Integrated Services Digital Network in North America," unpublished report (National Institute of Standards and Technology [NIST], National Computer System Laboratory, December 1988).

[11]George D. Kraft and Thomas R. DeWitt.

Interested individuals are allowed access to the NIU-BBS; membership in the NIU-Forum is not a requirement.

Each of the military services is developing ISDN capability and is active in the NIU-Forum. The Department of Defense (DOD) has prepared a preliminary network migration plan that includes integration of both narrowband and broadband ISDN into its future global telecommunications architecture. The General Services Administration (GSA) has also become active in the NIU-Forum and, as the Federal Telephone System (FTS) is renovated under FTS2000, ISDN capabilities are to be included as they become commercially available.

Over the years, there have been numerous demonstrations and commercial applications of ISDN technology. In January 1989, a unit of Bell Atlantic entered the ISDN arena by winning a large GSA contract for the Washington Interagency Telecommunications System.[12] The dedicated digital network will supply ISDN services to 130,000 government employees, and will connect to FTS2000 and the public telephone network. Army activities in ISDN include demonstration programs by the Army Institute for Research in Management Information Systems, Atlanta, and the Redstone Arsenal, AL.

[12] *ISDN News*, Vol 2, No. 1 (Phillips Publishing, Inc., Washington, D.C., 17 January 1989). p 1.

3 SOFTWARE DEVELOPMENTS

Regardless of the speed and complexity of computer hardware, it is the software that actually does the work for the user. It is generally acknowledged that software development has not kept pace with hardware development. *OS/2*, the second IBM microcomputer operating system, for example, utilizes only the capabilities of the 80286 processor even though the 80386 is the current state-of-the-art, and the 80486 is soon to be in the marketplace. Software developers are working hard to catch up, and many of the common types of software (such as word processors, spreadsheets, and databases) are constantly improving. Also, a number of new software categories are beginning to appear, some offering exciting new potential for the user.

In terms of impacting the operation of Army environmental offices, of greatest interest are programs written specifically to address environmental science and engineering problems. There has been active development in this area by both private vendors and government laboratories, notably the U.S. Army Construction Engineering Research Laboratory (USACERL). The latter portion of this chapter will survey some of these programs. First, however, trends in operating systems, general office automation software, utilities, and special purpose software will be examined.

Operating Systems

Operating system software is central to a computer system; it specifies how data is stored and handled, how the CPU is used by applications software, how memory is used, and how peripheral devices work with the CPU. There is a close connection between hardware and operating system capabilities. The design of *MS-DOS*, for example, was based on constraints inherent in the 8088 and 8086 hardware. Consequently, *MS-DOS* cannot fully utilize the capabilities of 80286 and 80386 machines, and neither can software running under *MS-DOS*. Key limitations of *MS-DOS* are its 640 kB memory limit and its inability to support multitasking. *OS/2* and *UNIX* do not share these limitations and are more capable of exploiting the power of the advanced CPUs. These capabilities come at a price; *OS/2* requires 2 MB of RAM and 8 MB of hard disk storage—and that is just for the operating system.

Because Army environmental offices will use a mix of machines with different CPUs, there will be a mix of operating systems as well. This mix will consist of Standard *MS-DOS*, enhanced *MS-DOS*, *UNIX* (including Apple *UNIX [A/UX])*, *OS/2*, and proprietary operating systems used by Apple and NeXT. The potential mix of the operating systems is of great interest to systems integrators and software developers. In the private sector, it is projected that by 1992, 30 percent of all microcomputers will use *OS/2*, 15 percent will use *UNIX*, 40 percent will use *DOS* and enhancers, and 15 percent will use the Apple system.[13] In the Army environmental office, *UNIX* may play a large role because this operating system is prevalent in engineering workstation applications, and because important USACERL environmental software is being developed for a *UNIX* environment.

A subset of operating systems that should be mentioned consists of *DOS* extenders, *DOS* enhancers, and *DOS*-compatible operating systems. *DOS* extenders such as Phar Lap's *386/DOS-Extender* or Qualita's *386-to-the-Max* improve the usage of RAM but do not really alter the way *DOS* operates. *DOS* enhancers, by comparison, are shells that insert themselves between *DOS* and the machine or between *DOS* and the user to add significant capabilities. Among other improvements, they allow multitasking of

[13]"Core Issues for 1989 in the PC Industry," panel discussion (COMDEX conference, Chicago, Spring 1989).

DOS programs. Three *DOS* enhancers are *Microsoft Windows*, *DESQview*, by Quarterdeck, and *VM/386* by Intelligent Graphics Corp. In contrast to *DOS* extenders and enhancers, *DOS*-compatible replacement operating systems retain no part of *DOS*. Instead, they are based on kernels that have been rewritten with multitasking design concepts. Two of the more popular replacement operating systems are *PC-DOS/386* by Software Link, and Digital Research's *Concurrent DOS 386*.

The present state of operating systems is similar to that of 10 years ago with *MS-DOS* and *CP/M*. After a period of coexistence, one or two operating systems will probably become dominant. Most feel the major contenders are *UNIX* and *OS/2*, but some analysts believe that *MS-DOS* enhancers may continue *DOS*'s presence into the mid-nineties.[14] The Apple Macintosh operating system should continue to be popular with users who place a high priority on graphical interfaces, but there is no concrete indication that the system will surpass in popularity the more widely used IBM-compatible systems.

General Office Automation Software

Word processors, spreadsheets, and databases are currently the main types of office automation programs. A look through the trade journals will reveal about 18 word processors, 16 spreadsheets, and 14 databases. Other important categories of office software include presentation graphics (12), communications (9), statistics (9), and utilities (more than 20). The number of programs available changes constantly, but these numbers should convey the bewildering assortment of choices that computer users are faced with in most categories of software.

Word Processing

Among the word processors, *WordPerfect* and *Microsoft Word* are probably the most popular. Other well known word processors are *Ami*, *Wordstar*, and *Q&A Write*. Word processing is probably the most mature category of desktop software and, as a result, almost all of them work well. Because of the development of graphical user interfaces such as *Presentation Manager* (for *OS/2*), and *Microsoft Windows* for *DOS*, the present trend in word processors is toward the graphical environment of desktop publishing introduced by Apple. The video monitor displays exactly what will print on paper. This approach is called "WYSIWYG" (pronounced "whizzy wig"), which stands for "what you see is what you get."

Spreadsheets

Spreadsheets are also following the trend toward using a graphical user interface. The prime examples are currently *Microsoft Excel* and *Wingz*, by Informix. The *Wingz* package, developed for the Macintosh, exhibits many features that will characterize the next generation of spreadsheets. First, like most products for the Macintosh, *Wingz* has a strong graphical user interface. Items like slide-bars, number wheels, and "radio buttons" allow creative alternatives for inputing and modifying spreadsheet data. *Wingz* also has tools for creating blocks of text and charts, as well as drawing tools for adding graphic touches to spreadsheets. These drawing tools are the same as those found in dedicated drawing programs: lines, rectangles, circles, and arcs, all of which can be resized, stretched, filled, and colored. Options include full color, three-dimensional charts for surface plots, wire frames, bar charts, and others.

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[14]Stephen R. Davis and W.L. Rosch, "When One PC Equals Four: 386 Multitasking Environments," *PC Magazine* (28 February 1989), p 95.

Titles and legends can be revised by changing the corresponding cells in the spreadsheet. These charting capabilities make *Wingz* an excellent tool for visualizing multivariate mathematical functions.

Wingz includes an integrated high-level programming language called Hyperscript. Instead of using cryptic macros (chains of commands executed by a single instruction) Hyperscript includes most common programming control structures (e.g., FOR/NEXT and WHILE loops) as well as IF/THEN/ELSE and CASE decision structures. The power of Hyperscript makes *Wingz* an excellent environment for developing customized applications. Because Hyperscript is clearly superior to macro languages, *Wingz* will compete with *dBASE*, *HyperCard*, and other database systems of application program development.

Databases

Several popular database packages (such as *Oracle*, *RBase*, *dBase*, *Foxbase*, and *Paradox*) are also used in application development. An important trend in database programs is the incorporation of Structured Query Language (SQL), which is presently used by about 25 percent of the mainframe database market. IBM designed SQL to be a standard language for accessing data independent of the hardware or software being used. Thus, database programs based on SQL can run on microcomputers, minicomputers, and mainframes, and can access data from other SQL-compatible databases. For example, a personal computer (PC) with an SQL database program can access data from any linked mainframe or mini without knowing where the data resides. The data appears as if it is located in the PC. Two databases for PCs that use SQL are *Oracle* and *dBase IV*. As more databases implement SQL, the potential for interconnection will increase, allowing PCs to access diverse mainframe databases in a transparent, user-friendly fashion.

Hypermedia

Hypermedia refers to a special kind of database that can link text, video, statistics, sound, animation, and graphics into an easy-to-use visual format that supports instant cross-referencing of concepts. Hypermedia systems differ from traditional relational databases in that data is stored in a nonsequential format that permits for nonsequential presentation of ideas. In a typical hypermedia application, a user reading a page of text on a computer screen could highlight an unfamiliar word, which would generate a window containing a definition, a picture, or even a full-motion video with sound, illustrating the meaning of the selected word. Since hypermedia systems allow users to collect, organize, and explore information by association, they parallel the way related ideas are organized in the human mind.

Hypermedia concepts have been implemented using various software tools (e.g., BASIC). Apple's *HyperCard*, however, is rapidly becoming the most common tool for developing hypermedia applications. The core of *HyperCard* is HyperTalk, an object-oriented programming language. In implementing hypermedia concepts, *HyperCard* has two strong virtues: a powerful and intuitive user interface, and great potential to be extended by supplementary routines called external functions (XFCNs) and external commands (XCMDs). XCMDs and XFCNs allow users to customize *HyperCard* to perform many complex tasks within the original framework of a hypermedia system. In general, *HyperCard* applications are impressive for their powerful graphical user interface and their ability to manipulate images at will. Challengers to *HyperCard* on the horizon are *InterMedia* (which runs under *A/UX* and was developed by Brown University) and *SuperCard* by Silicon Beach.

The user interfaces of hypermedia systems make them strong candidates as software tools for TRADOC environmental offices. If environmental engineering software is written using hypermedia concepts, the ease of use and short learning cycle may make them the best possible choice.

Artificial Intelligence

The science of artificial intelligence (AI) seeks to develop systems that emulate human intelligence. In the past it was generally believed that computers could never be used to realize this goal because of their limited speed and processing capabilities. It was believed that the sheer size and cost of a computer with the speed and memory capacity of a human brain would thwart attempts to develop AI. These predictions did not account for the exponential growth in computer speed and memory capacity or the simultaneous reductions in size and cost. One writer has pointed out that if developments in computer tchnology continue at their present pace, a machine with speed and memory capacity equal to the human brain will be available in the year 2010.[15]

For the present and near term, AI technologies will use conventional and neural network computers to produce systems that, while not truly intelligent, mimic intelligence in such tasks as decision making, image processing, and voice recognition—areas where conventional programming methods are ineffective. With the exception of neural networks, these systems achieve simple forms of reasoning and inference based on sets of preprogrammed rules. The most common form of this technology is the expert system.

Expert Systems

Expert systems are sets of rules, based on the experience of a human expert and incorporated into computer software, used to perform tasks normally done by a human expert. Areas of application include medical diagnosis, manufacturing process control, and air combat simulation. An expert system recently was used to monitor data from the Voyager spacecraft during its Neptune encounter. In environmental engineering, expert systems have been developed by Dupont of Canada to monitor treatment of waste from its nylon production process. It was found that even in a heavily automated plant, enough unexpected conditions can occur to require a waste treatment expert. The plant's resident troubleshooting expert, and other waste treatment experts, provided experience for this system, known as the Waste Treatment Plan Advisor. Operators at the plant consult the expert system for assistance in responding to alarms and other occurrences.[16]

Another area where expert systems are being applied is in database search. General Electric has demonstrated SCISOR (System for Conceptual Information Summarization, Organization, and Retrieval), which is an intelligent text retrieval system that extracts information from electronic databases based on concepts and terminology defined by the user. A related development is the SQL database connection developed by Carnegie Group of Pittsburgh, PA, for integrating knowledge-based systems and *Oracle* databases.

There are many software tools and C-based shells available for developing expert systems. Some of the better known packages are *LISP*, *Prolog*, and *SmallTalk*. Many of these tools are also beginning

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[15]Hugo DeGaris, "What if AI Succeeds?—The Rise of the 21st Century Artilect," *AI Magazine*, Vol 10, No. 2 (Summer 1989).

[16]David A. Blanchard, ed., "DuPont Turns To An Expert System For Waste Treatment," *AI Week*, Vol 6, No. 16 (15 August 1989).

to incorporate SQL and Hypertext capabilities. It is likely that, in the near-term, expert systems of one kind or another will find application in the TRADOC environmental office. Such systems could compensate for the departure of a staff expert by capturing his or her knowledge, or provide expertise in areas where the knowledge is used too infrequently to justify an expert's salary.

Utilities

Utilities are small programs (or sets of programs) that provide numerous useful functions. They frequently provide excellent value in terms of improving the productivity of a PC.

One simple, inexpensive, useful, and very successful utility is *Sideways*, by Funk Software. This $39 utility prints data and text sideways to overcome the limits of narrow printers. It provides a very inexpensive way to avoid a typical output bottleneck. This simple program often ranks as one of the top 10 selling software packages.

A number of other printer-related utilities aid in automated printing of standard forms (both preprinted and computer-generated). Examples include *Formworx* by Formworx Corp; *Horizon* by FormMaker Software, Inc., *JetForm* by Indigo Software, Ltd., and *Formfiller* by Bloc Publishing. Like *Sideways*, these utilities are relatively inexpensive and can go a long way toward eliminating an output bottleneck. Any group that must complete many forms in its work should explore a program of this type.

Another category of utility that can be useful is the disk manager, such as *XTree*, *ViewLink*, and *Lotus Magellan*. These programs, to varying degrees, allow flexible organization and visualization of the hard disk file structure. *Magellan* offers the capability of searching any file in any directory, at the text level. For example, if the user can't remember the filename of the letter to Jones Environmental, *Magellan* can search the text in every file on the disk for the words "Jones Environmental," and reveal exactly where it is.

Related to hard disk managers is the very useful category of disk maintenance utilities, among the best known of which is *Norton Utilities*. Most microcomputer users eventually need to be "bailed out" by one of the 27 data recovery and disk management tools that Norton provides. Besides "UnErase" (to bring back accidentally erased files) this package includes "Format Recover," which can unformat an accidentally formatted hard disk. Similar utilities are available in *Mace Utilities Gold*, *Disk Technician Plus*, and *SpinRite*.

Two other disk and system maintenance utilities are *AXE*, by System Enhancement Associates, and *System Sleuth*, by DTG. *AXE* can shrink large executable program files by as much as 60 percent. Embedded in the compressed code is a small routine, triggered when the program is executed, that decompresses the file so it works normally and transparently to the user. This program can be very useful, particularly for users of laptop PCs with limited disk storage capacity. *System Sleuth* is a diagnostics package that can run a number of tests on memory, peripherals, disks, I/O, processors, displays, and more. *System Sleuth* can find problems even when the user is not sure where to look. Utilities of this type will grow more useful as systems options and configurations increase in complexity.

Special Purpose Software

Special purpose software refers to programs that now, or will in the near future, stand alone as a specialized application. Examples are CADD (computer-aided design and drafting), project management,

communications, data security and virus protection, presentation graphics, and engineering applications software (including software for environmental engineering). As in the case of utilities, it is impossible to provide an exhaustive review in a report of this nature. This section will discuss special purpose software that may be relevant to important trends in environmental office automation.

CADD

While the mission of TRADOC environmental offices does not generally include design, there are situations in which some form of CADD software would be useful. Examples of such situations include generation of spill-prevention plans and providing building floor plans that map out the locations of hazardous materials for fire departments. CADD software available for microcomputers today varies in power from full-scale production-quality systems to rudimentary sketching programs. Regardless of their level of power, all CADD packages use "primitives," or "entities," to create drawings. Entities may consist of points, straight lines, parallel lines, rectangles, polygons, arcs, circles, and ellipses. Some packages also offer freehand sketching. Entities are placed on the screen by specifying their location through the keyboard, a mouse, or a digitizer. To help accurately align graphic elements to one another, most CADD packages provide grid and "snap" functions. Snapping acts like a magnetic force, pulling the cursor to the nearest point on the grid or endpoint of a line, the intersection of certain lines, or the midpoint of a circle. Many CADD packages allow drawings to be structured in layers, in the same way a draftsman uses acetate overlays. Some packages offer an optional bill of materials function that can create a list of required parts or amounts of required materials, based on the drawing. Advanced CADD packages provide 3D solid object and animation capabilities.

Of the CADD packages available today, *AutoCAD*, by AutoDesk, Inc., is probably the most widely known. This program accounts for nearly 50 percent of CADD installations, including mainframes and minicomputer workstations. *AutoCAD* is a sophisticated, full-featured package for professional designers. Some CADD packages are less expensive than *AutoCAD* but offer many of its features. Examples include *Generic CADD* by Generic Software, Inc., *Drafix 1 Plus* by Foresight Resources, Inc., and *AutoSketch* by AutoDesk.

Communications Software

When using a modem, the hardware that connects a computer to telephone lines, it is necessary to have a communications software package. These programs automate the sending and receiving of modem control commands and data, and provide many other useful functions. Communication software technology is well developed, and many reliable, low-cost packages are available. These programs generally offer features such as a dialing directory, automatic redial, the ability to emulate many different terminal types, file transfer capabilities using various protocols (e.g., Kermit, Xmodem, and Telink), and macros (for unattended operation). Some of the well known and effective packages available include *ProComm* by Data Storm Technologies, *Smartcom III* by Hayes Microcomputer Products, Inc., and *Crosstalk* by Microstuf. A useful software package specifically designed for communications between microcomputers is *pcAnywhere III*, by Dynamic Microprocessor Associates. This software lets a user run a microcomputer from any other IBM-compatible or Macintosh system. It provides complete control of the remote computer's programs, data, peripherals, and internal cards.

A special set of communications software facilitate communications between IBM-compatible PCs and Macintoshes. One of these packages, *SoftPC* by Insignia Solutions, runs on the Macintosh and emulates an Intel 80286 CPU, enabling Mac users to create a *DOS* partition on their hard disk. *SoftPC* runs in its own window on the Mac and emulates all aspects of an IBM-compatible PC. Other software

of this kind includes *MacLink Plus* from DataViz, *Lap-Link* from Traveling Software, and *PC-to-Mac and Back* from Dilithium Press.

Project Management Software

Project management software for microcomputers adapts powerful, time-tested project management tools (e.g., Gantt charts, PERT charts, and the critical path method [CPM]) to microcomputers. This software technology is well developed and more than 100 packages are available. While project management software requires as much input information as nonautomated methods (i.e., they don't plan the project for you), they are very helpful in a dynamic project environment. Changing and updating a plan, and projecting the impacts of the changes, are quick and easy. Most systems allow the development of resource summaries for both labor and materials, broken down by specific resource. Some packages even ensure that the project is scheduled within available resource and time constraints. Some packages allow the user to specify multiple time estimates (e.g., optimistic, pessimistic, and most likely).

Of the many project management software packages available, *SuperProject* by Computer Associates, *TimeLine* by Symantec, and *Project Scheduler 4* by Scitor Corporation are well known. Project management software may be useful for environmental offices that often face complex projects of moderate or long duration.

Security

Increased concern for microcomputer data and systems security has spurred the development of many useful security programs. While in the past some users have felt that security programs on a microcomputer were troublesome, confusing, and expensive, the newer software packages are easy to install, use, and maintain.

In most cases, data security consists of encrypting data files as the first line of defense against unauthorized access. Messages and data are encrypted by modifying each element according to a systematic pattern called the key. Only the correct key can decode the information.

Keys can be either public or private. With a private key system, both the sender and receiver of a message must know the key, but then there must be a secure method of transmitting the key if it is ever changed. Public key systems are designed to overcome this problem. In a public key system, each user has two keys, a public one for encrypting and a private one for decrypting.

The public key system works like a one-way trap door. Data is encrypted with a single public key but can only be decrypted with certain secret information—the private key. Thus, in a public key system, anyone wanting to send a message "can drop it through the trap door" with the public key, but only the receiver possesses the key for pulling information out through the "trap door."

One fast and inexpensive ($70) program providing file encryption is *File Encrypt* by Wisdom Software. *File Encrypt* is a single-key conventional cryptosystem that can run in both *DOS* and *OS/2*. Another encryption program is *Secret* Disk II, by Lattice. This program not only encrypts selected data, but also creates "invisible drives" for storing the encrypted files, thus providing two barriers to unauthorized access.

Some security programs protect the secrecy of data being transmitted between two modems. One is *MailSafe* from RSA Data Security. Because more than one user must have access to the secure data, both a public and a private key are used. Senders of the data use a public key to verify the recipient's digital signature and to encrypt messages for transmission. The recipient uses a private key to sign (acknowledge receipt of) files and decrypt the messages received.

Another approach to security is to deny access to disk operating system resources. One program that does this is *Watchdog* from Fischer International Systems. The easiest way to defeat a software security program is to boot (start the computer) from an independent disk; *Watchdog* prevents this by requiring the user to boot from a predetermined drive, usually the hard drive. From the time of log-on, the user interface produces a menu system that controls the user's access to authorized directories and files. *Watchdog* assigns permission levels to restrict reading, writing, creating, and deleting files, as well as the use of other *DOS* Commands. This program also provides an audit trail of all system activities by all users.

Virus Protection

A computer virus is a small, self-reproducing program that spreads itself among machines sharing floppy disks or a network connection. Viruses frequently ruin data or program files, and their spread has led to the development of software preventatives, diagnostics, and cures. Preventative programs keep a virus from infecting a system by prohibiting changes in executable files that viruses use as a foothold. Diagnostic programs detect a virus and warn the user only after infection has occurred; they may or may not provide a cure. The curative programs act as vaccines or benign viruses that inject themselves into the user's programs in an attempt to remove the offending virus. There are several known viruses, and no protective program is yet effective against all of them. Some widely known *MS-DOS* viruses are the Lehigh virus, the Pakistani Brain virus, the TSR virus, and the Alameda virus. Two Macintosh viruses are called Scores and nVir. Programs reported to be effective against the Lehigh virus are *Certus, Dr. Panda Utilities, Flu_Shot+, Mace Vaccine,* and *Vaccine.* Programs reportedly effective against the TSR virus are *C-4, Dr. Panda Utilities, Flu_Shot+,* and *Virusafe.*[17] Details on these and other virus protection software are included in the appendix.

Personal Schedulers

Tickler/2, by Enyart Development Corp., is an *OS/2*-based personal scheduling program that indicates the trend in personal productivity software. This program is the electronic equivalent of the familiar paper-based "tickler" files, but does much more. Not only does it remind the user to do things, it can remind the computer as well. Some observers believe this software is the precursor of a new family of programs that will use AI tools to automate the microcomputer more completely than ever, and promote its evolution into a dynamic electronic assistant.

Tickler/2 has two portions: one provides reminders and works in the background; the other operates in the foreground and is used to program the background portion. The background function provides reminders over a specified time period, and can be set to act in a "nagging" or countdown mode.

A powerful command called "execute" allows *Tickler/2* to automate the microcomputer in highly useful ways. This command will launch *OS/2* commands or batch files at a specified time or, using the

[17]Neil J. Rubenking, "Infection Protection," *PC Magazine* (25 April, 1989).

"named event" feature, after specified events have occurred. Since *Tickler/2* is designed to work with database, spreadsheet, electronic mail (e-mail), and project management software, it is capable of many automation tasks. For example, it could be configured to update an existing spreadsheet daily, print a report, and electronically mail it every week—all while the user is on vacation. Or, if a user needs to check his or her e-mail box every day, the program could be set to automatically do so every morning. Numerous possibilities exist for boosting user productivity. The concept behind this program is powerful, and it seems likely that other software developers will follow its example toward a new generation of microcomputer productivity software.

Environmental Software

In a recent review of environmental software, the journal *Pollution Engineering* estimated that the number of programs in this area has doubled each year for the last 5 years. Currently, it is estimated that there are more than 400 environmental software packages. Many perform a specific task or provide information on a narrow subject, while others perform many tasks. Some are modular and can be used in different combinations with other modules as needed. There is a software currently available to assist in almost every major environmental and safety area. This report will discuss several of the more notable programs now available. For more information, an excellent source for DOD environmentalists is the Environmental Technical Information System (ETIS)*, which provided information on most of the environmental programs described here. A list of vendors of environmental software and databases is provided in the appendix. Another useful guide is *The Environmental Software Directory*, published by Donley Technology, Garrisonville, VA. Some brief descriptions of environmental software follow.

General Programs

BeSafe, by Azimuth Technologies, Inc., is a modular software package consisting of modules for safety, health, and risk information. Modules include master reports as well as reports on injury, workers compensation, medical records, industrial hygiene, inspection, training class tracking, and fire.

ECOTRAC, by Solutech Corporation, is a comprehensive package that covers a wide environmental spectrum. The software consists of modules that can be combined or stand alone. Included are:

- Permit Tracking—maintains key information pertaining to environmental permits. Information includes responsible agency, limitations and stipulations in the permit, special permit handling information, and key dates.

- Environmental Events—tracks significant events including permit expirations, citations, inspections, spills, hearing and rulemaking dates, and environmental audits.

- Source Inventory—outlines sources of air, water, and waste emissions. Maintains information on toxic storage depots, manages monitoring data, and provides information on any source. Outlines specific pollutants by source, analyzes trends over time, and generates reports for submission to applicable agencies.

*For more information on ETIS, contact the ETIS Support Center, University of Illinois, at (217) 333-1369.

• Toxic Substances Control Act Management—keeps track of PCBs, asbestos, and other toxic substances at equipment level. Manages information pertaining to the type of equipment, date installed, service records, location, transport, and status. Maintains disposal records for retired equipment and lists those individuals responsible for a given piece of equipment.

• Groundwater Monitoring—manages data collected from monitoring wells. Performs averages, minimum, maximum, and standard deviations for each parameter. Tracks trends in data by well and parameter and allows up to four analyses per sample for all chemicals analyzed per well. Provides for statistical testing using the Student's T-test.

• Manifest Tracking—reports transit manifests for hazardous and toxic waste disposal. Reports open manifests and exception management reports (e.g., loss, spill, etc.). Records party responsible for shipments and includes data for final toxic storage depot. Includes a trial balance report for wastes to determine total balance of toxic wastes for a given facility. Produces the Uniform Manifest Form as a standard report and assists in verifying waste minimization program effectiveness.

• Drum Inventory—tracks contents and locations of drums from the date they are packed to ensure compliance with 90-day storage limits. Detailed waste information is also tracked in drum contents reports. Produces summary reports of drums shipped and drums in storage.

• Radiation Waste Management—specifically designed to track the disposal of radioactive waste materials. Reports total quantities, activities, and form of contaminants so complete waste inventories can be obtained. Monthly summary reports can be generated with up to five user-determined selection criteria.

Enflex Data, by ERM Computer Services, is another comprehensive environmental information and data management system. Its modules include Superfund Amendment Reauthorization Act (SARA) right-to-know inventory, permits tracking, National Pollutant Discharge Elimination System (NPDES) reporting, manifests, groundwater monitoring, PCB recordkeeping, auditing, air emissions, underground storage tanks, drum tracking, environmental events, fugitive emissions, calendar, and Material Safety Data Sheets (MSDS).

Other comprehensive environmental software packages include the *Environmental Compliance Management System (ECMS)* by Versar, Inc., and *The Environmental Manager (TEM)* by Environmental Information Systems, Inc. *TEM* includes a query function that uses SQL (discussed under database software). Versar also offers a program for underground storage management called *SmartReg*, which is implemented in Apple's HyperTalk, the scripting language of *HyperCard.*

Software packages pertaining specifically to the hazardous materials area include:

Chemdata, by Aqua Tech, Inc., is an emergency response computer software system. It contains information on more than 19,000 chemicals and 49,000 synonyms. It offers the ability to search its database by chemical name, part of a chemical name, and United Nations (UN) and North American (NA) chemical numbers. The system then displays all known information about the chemical, including its hazards, response precautions, emergency protective gear specifications, fire fighting procedures, first aid, and decontamination procedures.

HAZM (Hazardous Waste Manager Network), by Z Micro Systems, keeps records of disposal manifests including information on sites, quantities, categories, and transporters. It prints state manifests on official forms and outputs reports by waste category, transporter, and disposal site. *HAZM* also keeps records from MSDSs provided by suppliers.

Hazardous Material Information Network (HAZMIN), by Logical Technology, Inc., is a total system for hazardous materials within a facility or corporation. *HAZMIN* provides the ability to comply with U.S. Department of Transportation (DOT) placarding, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reporting, Hazard Communications Standard (HCS) use history, Resource Conservation and Recovery Act (RCRA) disposal regulations, right-to-know training, and SARA documentation.

*OSHA-Soft CFR**, by OSHA-Soft Corporation, includes 29 CFR U.S. Occupational Health and Safety Administration (OSHA) and 40 CFR U.S. Environmental Protection Agency (EPA) on disk. A user can look up regulations by word, phrase, section number, or subject matter. The program is updated annually.

Databases

Environmental databases are available as on-line services or as CD-ROMs, and some are available in both forms. On-line databases include the EPA's *Oil and Hazardous Materials Technology Assistance Database (OHMTADS)*, *HAZARDLINE*, which contains regulatory, health, and precautionary data on over 78,000 hazardous chemicals, *NIOSHTIC*, a database maintained by the National Institute for Occupational Safety and Health that contains occupational health and safety information, and *WETLANDS*, a national database of state wetland protection programs and contacts.

There is also a database of databases. The National Environmental Data Referral Service (NEDRES) maintains a computer database directory for sources of environmental data. It is available to the public and allows easy access to information that could be useful to environmental offices. The NEDRES database identifies the existence, location, characteristics, and availability of environmental data. It is maintained by the National Oceanic and Atmospheric Administration (NOAA) and is accessible by computer terminal using the *Telenet* or *Tymnet* on-line networks.

Databases available on CD-ROM include *Micro-OHMTADS* from Artificial Intelligence Applications Corp., *OSH-ROM* and *PEST-BANK* from Silver Platter, Inc., and *ENFLEX Info* from ERM Computer Services, Inc.

More information on environmental databases can be acquired from NEDRES, as well as the previously mentioned ETIS and Donley directory. The Appendix also has information on some of the databases available.

In addition to the software and databases available commercially, USACERL has developed many environmental software and database products. ETIS offers USACERL-developed databases such as the *Computer Aided Environmental Legislative Data System (CELDS)*, the *Hazardous Material Management Systems (HMMS)*, and the *Economic Impact Forecast System (EIFS)*. Also developed by USACERL (and available through USACERL or other agencies) is a wide variety of programs, ranging in capabilities from

*CFR is Code of Federal Regulations.

broad (e.g., the *Geographic Resource Analysis Support System [GRASS]*) to narrowly focused (e.g., *DB1383*, a program for generating EPA 1383 forms, available through the U.S. Army Toxic and Hazardous Materials Agency [THAMA]). More information on USACERL environmental software can be obtained by contacting the USACERL Environmental Division (EN) at 800-872-2375 (outside Illinois), 800-252-7122 (in Illinois), or FTS 958-7255.

4 ENVIRONMENTAL OFFICE ACTIVITIES

The TRADOC installation environmental offices are responsible for the installation's compliance with Federal, State, and local environmental regulations. Areas as diverse as hazardous waste management, air and water pollution, wildlife management, and archeology fall within the responsibilities of these offices.

The areas of training and expertise of the environmental office staff reflect the diversity of its mission. Disciplines represented include environmental science, environmental engineering, civil engineering, ecology, biology, entomology, forestry, planning, agronomy, and archeology. Because of the variety of backgrounds and formal training among personnel, there is a wide range in the staff's level of computer literacy.

Typical environmental office operations consist of environmental audits, permit tracking, monitoring air and water pollution emissions, monitoring groundwater quality, landfill management, MSDS management, waste manifesting, storage tank monitoring, and inspection for hazardous materials (e.g., asbestos, PCBs, and radon). These activities keep the installations in compliance with RCRA, CERCLA, and SARA requirements.

Much of the environmental office's activities consist of inspection, testing, recordkeeping, analysis, and reporting. The focus of these processes may be items as diverse as training areas, forests, archeological sites, transformers containing PCBs, buildings containing asbestos, and underground tanks.

Inspection and testing generally seek the answers to basic questions such as what is it, where is it, and how much is there? Inspection and testing are the input phase of much of the environmental management process. Their purpose is to determine what pollutants are entering the installation or are being generated, how much is present, and how much is being disposed of or entering the environment.

The process of recordkeeping, analysis, and reporting involves gathering the data from inspections and tests, giving it a meaning or context through analysis, and producing the reports required internally and for various regulating bodies. To illustrate: when hazardous materials are discovered through an inspection, their properties must be determined, safety precautions must be implemented, exposed personnel must be informed, any relevant training requirements must be identified, and the applicable regulations must be determined. This information is recorded with the inspection data and reports are generated to summarize the results of inspection, testing, and analysis. These reports are prepared for the various agencies in whatever format is required. As a body of information, the reports document the installation's overall environmental impact and show that it is in compliance with applicable permit requirements and regulations.

Other office activities include periodic review of environmental legislation and regulations and response to environmental incidents or emergencies. These incidents can range from hazardous chemical spills, the explosion of a transformer containing PCBs, the failure of a boiler plant baghouse, or "mysterious" brown spots on someone's lawn.

Two of the four TRADOC installation environmental offices surveyed for this report provided information on their time spent on various activities. Their responses do not agree for every category of activity, indicating that each office views its job differently. The second installation, for example, did not consider inspection and testing, and analysis and reporting, as separate activities, and referred to them as "program management." The responses of the two installations are included in Table 2.

Table 2

Percentage of Time Devoted to Various Environmental Office Activities

	Installation A	Installation B
	10% Researching environmental requirements	2% Researching environmental requirements
	25% Meetings and communications with installation personnel	8% Meetings and communications with installation personnel
	25% Inspection and testing	60% Program management
	30% Analysis and reporting	6% Response to regulations
	10% Accidents and emergencies	12% Accidents and emergencies
		12% Personnel management
TOTALS	100%	100%

Most of these activities could be streamlined by office automation/information technologies. All four of the installation environmental offices surveyed have microcomputers: one office has nine PCs with seven more on order, two offices have five PCs, and one office has one PC. Each EN office has a word processor and spreadsheet program, and three of the four have a database program. In each office there was an individual on staff identified as the "computer expert." The skill level of these experts varied, but this issue was not specifically addressed in the survey.

The level of OA/IT implementation varied with the staff's computer literacy. One installation said the staff knew it needed to automate but did not have the time or skills. Another installation, however, claimed complete automation, using staff-written or USACERL programs for management of radon, asbestos, underground storage tanks, PCB transformers, and 1383 report documentation. The other two installations, by comparison, reported that the staff was just beginning to use USACERL and staff- or contractor-written programs. Problems encountered in using software supplied from out of house included lack of time to learn to use the software, and insufficient computer memory to load the software. In several cases, software was sitting on the shelf for one or both of these reasons.

Each installation EN office was asked to produce an OA/IT "wish list" based on everyday staff experience as well as technologies that came to their attention during interviews for this research.

The responses to this part of the survey are listed in Table 3. No order of priority is implied.

Durin. .ssions of wish list items the interviewees were informed of developments such as bar coding, lapt. .puters, hand-held computers, and cellular telephone interfaces. These devices seem to have great pot. .al in the area of remote data acquisition and recording, but surprisingly little interest was shown in these technologies. This may indicate either that there is little need for assistance in data acquisition or that currently available products are not meeting the right needs.

Observations made during the research for this report indicate that both TRADOC installation and headquarters environmental offices appear to be overloaded with work. Difficulties were observed in the staff's ability to return phone calls, schedule site visits, and provide reports from files in a timely manner. Office personnel were cooperative with the authors, but were often unavailable because of field emergencies. It was apparent that the workload made it virtually impossible for personnel to plan more than a day or two in advance. It seems clear that the kinds of productivity increases resulting from OA/IT applications could offer important benefits to environmental office personnel and, therefore, to the Army's environmental activities.

Table 3

OA/IT "Wish List" From Selected Environmental Offices

Installation A	Installation B	Installation C	Installation D
Fax board	Voice-actuated input	Fax board	32-bit super-micro or Sun workstation
Voice mail	More PCs	Document scanner	Scanner
Document scanner	Easier procurement	Computer storage of documents	Possibly a NeXT machine
Laptop PC		Software for producing forms	GRASS software for a desktop PC
Computer-generated 35mm slides		Simple CADD package	
A utility to print sideways		Technology to permit work at home	
Technology to integrate field sketches into reports			
Technology to permit work at home with PC			

5 APPLICATION OF OA/IT TO THE ENVIRONMENTAL OFFICE

The TRADOC environmental offices studied for this report appear to be overloaded with work. The need for assistance is clear, but hiring more staff is financially or organizationally unattainable. The classic management goal in such a situation is to increase the productivity of the existing staff. In the present case, the implementation of OA/IT is the most viable solution. As always in the case of staff overload, however, the introduction of the technology must be managed very well so productivity does not decrease instead of increasing. What follows is a projection of what the authors believe to be a feasible scenario for implementing OA/IT to improve the productivity of TRADOC environmental offices.

The Short-Term Future (1990-1992)

In the immediate future, it is recommended that office automation efforts should concentrate on improving the efficiency of information input and output. Three technologies in order of priority are recommended: text and graphics scanners, voice mail and fax cards, and programs to print forms. It is assumed that implementation will be on currently available microcomputers using 8088, 8086, 80286, 68020, or 68030 CPUs. These technologies are appropriate for offices with low or medium levels of computer literacy and only basic skills in the use of word processors, spreadsheets, and databases. The proposed technologies are simple, work-out-of-the-box products. Likewise, the capabilities they provide are simple, direct, and generally applicable to most environmental office functions.

The scanner would be useful whenever hardcopy text needs to be incorporated into a computer file for use by a word processor, spreadsheet, or database. Possible applications include the incorporation of job descriptions into training plans, the incorporation of hardcopy MSDS data, and the conversion of many existing hardcopy documents (e.g., contractor reports) into digital form.

The voice mail and fax card would save time and improve communications by eliminating "telephone tag." This technology could take messages from (or leave them for) callers, potentially saving from 1/2 to 1 hour per day per person. The fax card would also save time by speeding correspondence and eliminating bottlenecks at central fax units.

The form-generation software would speed completion of the many repetitive forms produced to comply with Federal, State, and local regulations. It is estimated that implementation of these three technologies in a four-person, four-microcomputer team will save 1 to 2 hours per person, or 4 to 8 person-hours a day. The estimated annual increase in productivity for the team would be between 1/2 and 1 person-year. This added efficiency is potentially the equivalent of hiring an extra full-time staff member. The cost of the technology specified above is estimated in Table 4. Figures are based on vendor contracts.

It is recommended that some of the time savings achieved by implementing this technology be invested in computer training right away. Recommended training would include instruction in appropriate environmental software packages. Training in specific applications is recommended instead of general training in spreadhseet and database usage. It is unreasonable to expect that most environmental scientists would have the time or inclination to develop their own applications based on generalized training.

Table 4

Cost to Implement Recommended "Near-Term" Technologies (1989 dollars)

Technology	No. of Units	Est. Unit Cost	Total
Desktop document scanner with optical character recognition card and software	1	$4935	$4935
Voice mail/fax card, software	4	$ 899	$3596
Form generation software	4	$ 81	$ 324
GRAND TOTAL			$88[illegible]

Other technologies that could benefit environmental offices in the immediate future are CD-ROMs and erasable optical disks, simple CADD packages, LANs, and disk-based or on-line environmental databases. The impact of these technologies will depend on the office's need and computer literacy of the users. Effective use of a LAN, for example, requires understanding microcomputer file structures and communications techniques, as well as an experienced LAN manager who can properly configure and debug the network. Similarly, effective usage of on-line databases usually requires training, and training time will not be abundant in the 1990-1992 time frame because of the continuing work overload.

The Mid-Term Future (1993-1995)

This time period will be marked by an increase in computer literacy of the average environmental office computer user. This will be due in part to the increase in training time resulting from the first wave of environmental OA/IT implementation, and partly because most users will by now have 3 to 5 years of experience in an OA/IT office environment. The increased literacy of the users, coupled with technology impacts during this period, should result in a sharp productivity increase. The technologies being implemented during this period will include full use of the multitasking capabilities and speed of advanced CPUs running in *OS/2*, *UNIX* or the Macintosh operating system. Typical machines will operate at 33 to 70 MHz and have hard disk capacities ranging from 65 to 300 MB. Erasable optical disk storage systems for importing databases and storing in-house data will be common. LAN usage will also be widespread and ISDN systems will be available at some installations. The major source of productivity improvements will come about through effective use of environmental software designed with a strong graphical user interface and fully compatible with *OS/2*, *UNIX* or Macintosh multitasking capabilities. On-line and in-house database resources will routinely be used and integrated into internal and external reporting requirements. Many external reporting requirements will be met by modem or the mailing of floppy disks. During this period most environmental reporting requirements will be completely and effectively automated. The typical four-person, four-microcomputer team will be equipped approximately as follows: one machine using a 80386, 80486, or 68040 processor running at 33 to 70 MHz in *UNIX*, used primarily to support large integrated software packages such as *GRASS* or other powerful environmental software; a second machine with similar CPU operating in *OS/2* acting as a nondedicated

LAN file server; two (old) 80286 or 68030 machines running under *OS/2* (or possibly enhanced *DOS*); a 16 or 10 Mbit/sec LAN; one optical disk drive (erasable); one laser printer, two (old) dot matrix printers; and a presentation graphics development system. Productivity improvements over the 1990-1992 level for a four-person team would be about 8 to 16 hours per day. Annual productivity improvements for the team would range from 1 to 2 person-years over the preceding period.

Costs estimated for implementing the recommended mid-term technologies are listed in Table 5. Figures are based on current vendor contracts. It should be mentioned that the estimation of future technology costs is based on the observable phenomenon of price declines as cutting edge technology is widely adopted by mainstream users. Figure 4 shows the pricing trend for 16 MHz 386-based machines from 1986 through 1989; this technology dropped from a high of $8000 to less than $3500 in 4 years—more than a 50 percent decline. Figure 5 shows an even more dramatic price decline in 25 MHz 486 machines from April through September 1990: in these few months the price fell from nearly

Table 5

Estimated Cost to Implement Recommended "Mid-Term" Technologies (1993 dollars)

Technology	No. of Units	Est. Unit Cost	Total
80386/50 MHz with 300 MB ESDI hard drive	1	$7299	$7299
80386/50 MHz with 100 MB ESDI hard drive	1	$6000	$6000
16 Mbit/sec Token Ring LAN cards	4	$595	$2380
LAN software	1	$995	$995
Optical disk drive (600 MB erasable)	1	$2500	$2500
Laser printer	1	$3500	$3500
Presentation graphics hardware and software	1	$7990	$7990
Environmental applications software	16	$600	$9600
		Total	$40,264

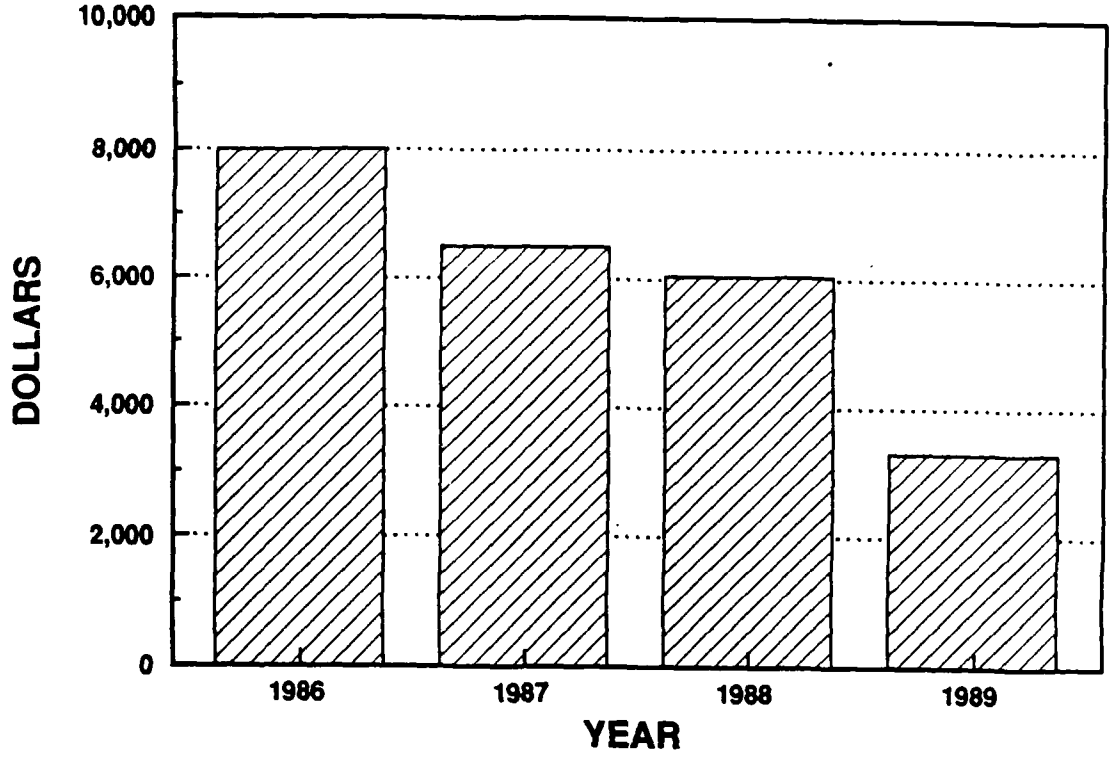

Figure 4. Pricing trend for 16 MHz 386-based microcomputers, 1986 through 1989. (Source: B. Brown and S.K. Losee.)

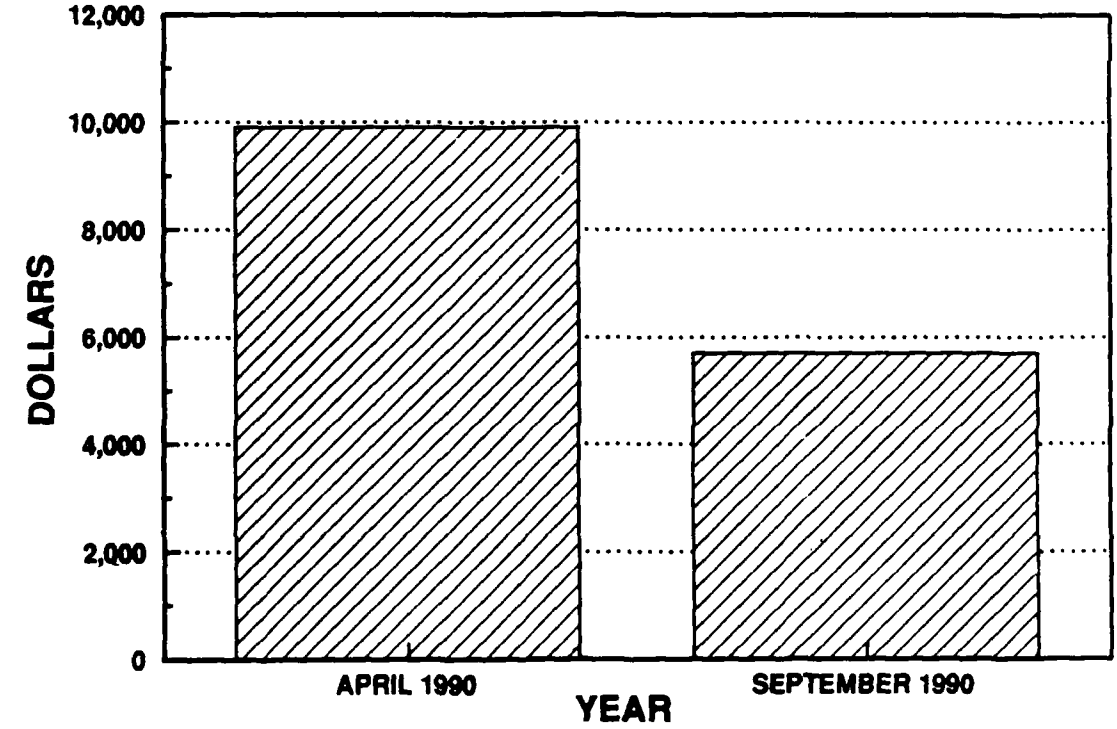

Figure 5. Pricing trend for 25 MHz 486-based microcomputer, 1990. (Source: *PC Magazine*, vendors' published prices.)

$10,000 to about $5500. There is a clear and demonstrable history of computer technology price declines as each succeeding generation of improved technology pushes the previous state-of-the-art equipment down into the domain of the mainstream mass-market user. This amounts to a kind of de facto price stability for improving technology—a side benefit of the OA/IT revolution.

Long-Term Future (1996-2000)

Entering this time period, the environmental office will have had several years of experience using advanced environmental software packages. The core duties of compliance with regulations will be handled routinely and effectively. Some programs, such as PCB transformers and radon management will be winding down, but other concerns will arise to replace them. It is projected that during this period the microcomputer (or microcomputer network) will begin to develop into a desktop robot assistant. This period will see the introduction of "overseer" software to orchestrate the completion of complex tasks, such as monthly or annual production of various environmental reports. These programs will include advanced applications of principles used in the *Tickler/2* productivity software discussed in Chapter 3.

The overseer program will receive instructions by voice or keyboard; it will work in the background, occasionally prompting the user for input or direction—probably by voice. An overseer program could serve as a receptionist to handle both vocal and digital telecommunications. The professional staff would assign their computer "assistants" tasks to be completed in the background while they used the machines for tasks requiring human intelligence. Parallel processing will be supported by overseer software using either plug-in transputer cards for 80486 machines, dedicated desktop parallel processors, or a virtual parallel processing machine created using the LAN. Performance of complex tasks requiring extensive database searches or advanced computation might be assigned to the network for completion at night. The network could even contact specified personnel at home (at reasonable hours) for instructions to deal with unforeseen problems. Long periods of unattended operation would require a high quality uninterruptible power system as part of the office equipment.

To perform a complex task such as report generation, it is likely that overseer software will require some kind of "learn" mode. This learn mode will be quite powerful, relying on AI and neural network adaptive learning techniques. While in the learn mode, the software will observe the steps taken by the computer operator to produce the desired report, and may even interject questions by voice or pop-up windows. After observing the staff member produce the report, the overseer software will have been trained to perform the task on its own.

Environmental simulation software will also be reaching maturity during this time. Continued improvements in computer speed and memory capacity and better graphical user interfaces are needed to implement effective environmental simulation programs. Such programs will allow TRADOC environmentalists to simulate and visualize environmental changes that may result from particular events. For example, a spill-planning program might be able to display a 3-D view of an above-ground storage tank, the local topography, and locations of escape points (e.g., streams, rivers, and sewers). This simulation would allow visualization of the effects of spills of various magnitudes, the effects of planned mitigation efforts, and methods of improving existing mitigation plans. Other simulations might allow visualization of effects of various training activities on an installation's environment, allowing projections of the effects at 5, 10, and 15 or more years into the future.

Estimated costs for the recommended new hardware and software for a four-person environmental team is listed in Table 6.

All of the hardware technologies described in Table 6 exist today. The 80486 CPU is not commercially available at 70 MHz yet, but should be before 2000. The major technologies that must be developed are the overseer software and versions of network, spreadsheet, and database software that support parallel processing.

Labor savings due to the implementation of the long-term technologies are estimated to be 1/2 to 1 person-years for a four-person team. The overall projected effect of OA/IT on productivity from 1989 to the year 2000 is shown in Figure 6.

Table 6

Estimated Cost to Implement "Long-Term" Technologies (1996 dollars)

Technology	No. of Units	Est. Unit Cost	Total
80486/70 MHz with 500 MB ESDI hard drive	1	$7000	$7000
80486/70 MHz with parallel processor board and 300 MB ESDI hard drive	1	$9000	$9000
100 Mbit/sec FDDI LAN cards	4	$3000	$12,000
LAN software supporting parallel processing	1	$2000	$2000
Optical disk system 1 Gigabyte	1	$4000	$4000
Overseer software	4	2000	$8000
GRAND TOTAL			$42,000

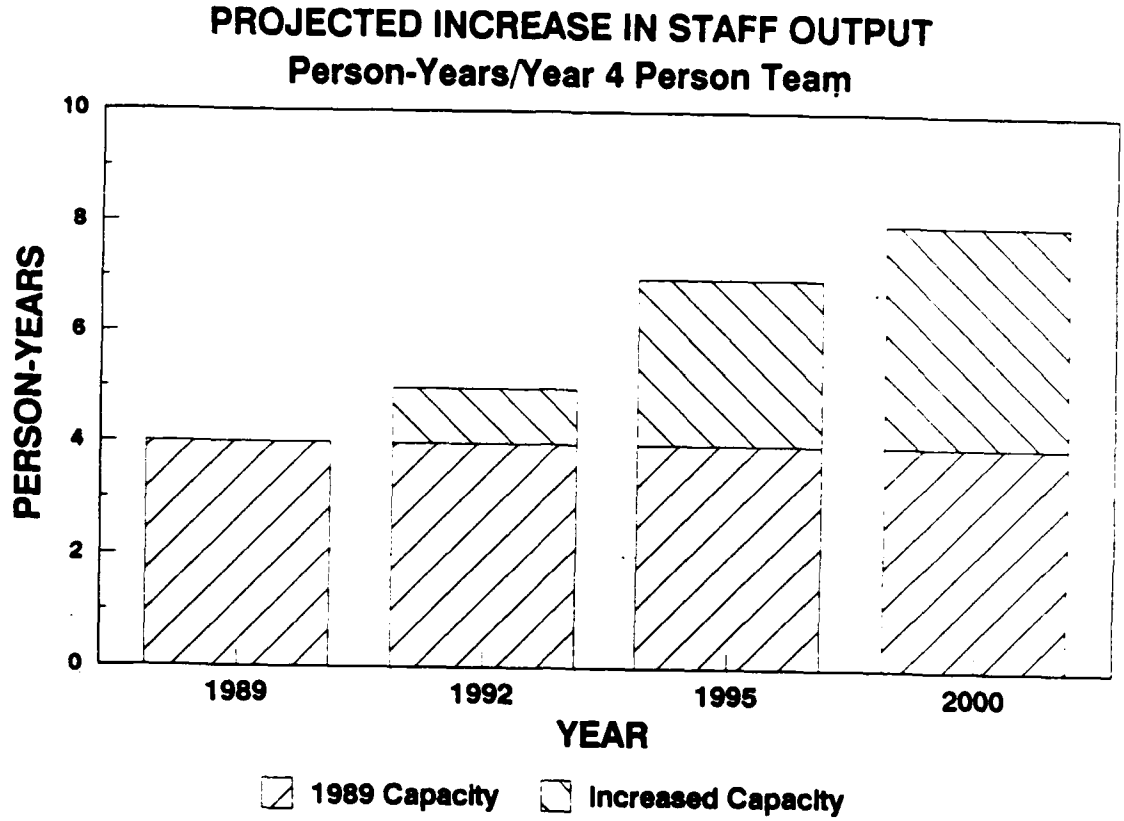

Figure 6. Projected productivity increases in EN offices using recommended OA/IT applications.

6 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The field of office automation/information technology is vast and changing rapidly so that this report has been able to produce only a quick sketch based on existing technologies. It is clear that hardware capabilities have been increasing at an exponential rate. As illustrated in Figures 4 and 5 previously, this rapid increase in capability has lead to large reductions in the user's cost for a specified level of performance. This trend seems likely to continue and, for this reason, projections of costs for year 2000 hardware were not difficult; the costs will be similar to that of mature technologies today, but the equipment will be much more powerful. The trend in software development, however, has been linear, not exponential. Therefore, software capabilities have not kept pace with the potential offered by the most powerful hardware. However, advanced artificial intelligence technologies such as neural networking may spur rapid advances in software. If this occurs, the age of "digital office assistants" could begin before the 21st Century.

Examination of typical environmental office activities at four TRADOC installations has revealed that there are many different items of environmental concern, but the process of managing these concerns is similar for many of them. The fundamental function of environmental offices was discovered to be the processing of environmental information. Basically, the environmental office gathers and inputs information about an installation's environment, analyzes this information, and produces output (e.g., reports, contracts for remediation efforts) based on the analysis.

Because the environmental office serves primarily an information processing mission, the potential impact of automated information processing technology is tremendous. This research suggests that a 100 percent increase over 1990 levels of staff productivity can be achieved by the year 2000. This projection is quite realistic. Research by Massachusetts Institute of Technology (MIT) school of business indicates that Standard Oil's introduction of information technology resulted in a 50 percent reduction in staffing.[18]

The Environmental Office of the Year 2000

In the year 2000 the TRADOC environmental office staff of scientists and engineers will be assisted by a network of microcomputers. The machines will run at 50-70 MHz and produce 100-150 MIPs using RISC, VLIW, and parallel processing techniques. Most permanent and semipermanent information will be stored on computer disks, both optical and magnetic, which will hold billions of bytes of information. A fiber optic LAN operating at 100 Mbits/sec will connect the microprocessors and ISDN communications will link all installation environmental offices to TRADOC headquarters, and to each other.

Software in the year 2000 will empower computers to perform as multiple office assistants both individually and as networks. Software will enable mainstream office computers to prepare reports, answer telephones, and gather data from mainframes and supercomputers—all in response to relatively simple spoken or written instructions. The network will possess the ability to learn and many of its tasks will be taught rather than programmed. The net result will be the equivalent of creating up to one full-time assistant for each professional member of the staff. Furthermore, powerful user-friendly simulation software will promote easy and accurate analysis of complex environmental situations resulting from

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[18] Robert B. Horton, *Some Thoughts on the Information Technology Revolution in Standard Oil*, publication 90S 86-029 (Massachusetts Institute of Technology Sloan School of Business, November 1986).

installation activities. Ideally these developments will result in an environmental office with the staff resources to take a proactive role in improving the installation environment, and the environment in general.

Recommendations

An MIT study concludes that the benefits of OA/IT depend on what the user expects. Low and high expectations can both be self-fulfilling prophecies.[19] The strategy for implementing OA/IT as presented in this report is simple: first, give the professional staff basic, easy-to-use tools to solve problems of input/output inefficiency. Then use some of the time gained through increased productivity to train the staff to use selected environmental software.

Training and User Support

The importance of training on specific environmental software cannot be overemphasized. Staff should be trained to use tested, approved, effective software that has been demonstrated to improve the performance of a specific environmental task. Environmental scientists and engineers are not expected to build their own computers; they should also not be expected to write their own software.

Some members of the environmental office staff do write software, however, and the best use should be made of it. One useful way to support training programs and higher productivity is to sponsor a software users group. The group might publish a newsletter dedicated to environmental software or a computer bulletin board system. These activities could be co-sponsored by USACERL and TRADOC headquarters and possibly staffed through the ETIS support center. Beside reviewing and distributing software produced in house, these groups could also review USACERL and commercial programs. It should be added that commercial vendors are often very receptive to providing software samples and presentations on their products to users groups and potential clients.

Measuring Performance

The task of measuring performance is sensitive because to many it brings to mind the image of stern people with stop watches conducting endless time and motion studies. This kind of performance measurement is not what is needed. Instead, TRADOC environmental offices need to formally define their common core tasks. Then, through discussions among the environmental office staffs and TRADOC headquarters, useful measures of performance can be developed. These might involve quantifying indicators such as the number of spills per month, the number of personnel trained in safety procedures, the percentage of reduction in an inspection backlog, the number of days without smoke emissions, etc. The important thing is for everyone to agree beforehand that the indicators are fair and relevant.

With appropriate performance measurement tools in hand, progress can be made toward the ultimate goal: a constantly improving environmental office.

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[19]Robert B. Horton.

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APPENDIX

OA/IT HARDWARE AND SOFTWARE RESOURCES

The following is a directory of representative vendors that produce microcomputers, operating systems and related programs, add-on processor boards, input/output peripherals, and applications software. This directory includes large and small manufacturers and publishers referred to in the body of the report. Prices cited are based on manufacturer advertisements published at the time this research was carried out. Because OA/IT technologies tend to evolve rapidly and are updated frequently, it is inevitable that some products listed here may already be discontinued or superseded. This directory is not intended to be exhaustive or completely current, but it provides a reliable starting point for those who seek technical information about the technologies discussed in this report.

CPUs and Microprocessors

Microcomputers
Compaq Computer Corporation
P.O. Box 69200
Houston, TX 77269
713-370-0670

Manufactures complete range of IBM-compatible microcomputers including desktop and laptop units using 286 and 386 CPUs.
Price: $2,000 to $10,000

Microcomputers
IBM Corporation
360 Hamilton Avenue
White Plains, NY 10601

Manufactures a complete range of microcomputer products and peripherals. Models include XT, AT, and Personal System 2.
Price: $2,000 to $10,000

Microcomputers
Apple Computer, Inc.
20525 Mariani Avenue
Cupertino, CA 95014
408-996-1010

Manufactures complete line of microcomputers and peripherals. Models include Mac Classic, SE30, IIci, IIfx.
Price: $1,000 to $10,000

Microcomputers
Dell Computer Corporation
9505 Arboretum Boulevard
Austin, TX 78759-9969
800-426-5150

Manufactures IBM-compatible microcomputers. Models include 80286 and 80386-based machines.
Price: $2,000 to $10,000

Microcomputers
CompuAdd Corporation
12303 Technology Boulevard
Austin, TX 78727
800-999-9901

Manufactures IBM-compatible microcomputers. Models include 8088, 80286, and 80386-based machines.
Price: $600 to $7,000

Microcomputers
Zeus International Ltd.
530 5th Avenue NW, #1000
St. Paul, MN 55112
800-423-5891

Manufactures IBM-compatible microcomputers. Models include 80286 and 80386-based machines.
Price: $1,300 to $5,000

Microcomputers
Gateway 2000
P.O. Box 2000
Sgt. Bluff, IA 51054
712-943-2000

Manufactures IBM-compatible 80286 and 80386-based machines.
Price: $2,000 to $4,000

Microcomputers
Everex
48431 Milmont Dr.
Freemont, CA 94538
800-356-4283

Manufactures IBM-compatible 80286 and 80386-based microcomputers.
Price: $2,500 to $7,000

Microcomputers
Zenith Data Systems
1000 Milwaukee Avenue
Glenview, IL 60025
312-699-4800

Manufactures complete line of IBM-compatible microcomputers and peripherals, including Z-1000 multiprocessor computer.
Price: $2,000 to $50,000

AT Super 50Mhz RISC coprocessor board
Yarc Systems
5655 Lindero Canyon Suite 721
Westlake Village, CA 91362
818-889-4388

AT-Super has a 50 Mhz AM29000 32-bit RISC coprocessor, which is used to upgrade 286-based computers. Performance is rated at 17 MIPS.
Price: $4,495

Parallel processor board for PCs
Micro Way
P.O. Box 79
Kingston, MA 02364
508-746-7341

Manufacturers Monoputer/2 and Quadputer parallel processing boards for microcomputers. Boards use T414, T425, or T800 transputers.
Price: $2,000 to $16,000

The Brain Simulator
Abbot, Foster and Hausermann
44 Montgomery, Fifth floor
San Francisco, Ca 94014
415-955-2711

Publishes tutorial software for neural circuit design.
Price: $99

BrainMaker
California Scientific Software
160 East Montecito, Suite E
Sierra Madre, CA 91204
818-355-1094

Neural network simulation software that runs in DOS environment. Supports five types of nodes; can process 500,000 connects.
Price: $99.95

Cognitron
Cognitive Software, Inc.
705 East 30th Street
Indianapolis, IN 46205
317-924-9988

Neural network/parallel processing prototyping and delivery system. DOS, Mac, and INMOS transputer versions are available.
Price: $600 to $1,800

MD/210 Fuzzy Set Comparator
Micro Devices
5695B Beggs Road
Orlando, FL 32810
407-299-0211

Hardware implementation of Hopfield neurons.
Price: $38

NeuroShell
Ward Systems Group, Inc.
228 West Patrick Street
Frederick, MD 21701
301-662-7950

Creates neural network applications using a modified back-propagation algorithm; runs under DOS.
Price: $195

Input Devices

EZBarCode
TimeKeeping Systems, Inc.
12434A Cedar Road
Cleveland, OH 44106
215-229-2579

Bar code printers and readers for microcomputers.
Price: $49 to $289

Bar code system
Lowry Computer Systems, Inc.
7100 Whitmore Lake Road
Brighton, MI 48116
800-556-7200

Integrated bar code information management system for PCs and mainframes.

Bar code reader
Caere Corporation
100 Cooper Court
Los Gatos, CA 95030
408 395-7000

Bar code readers for microcomputers and terminals.

JetForm
Indigo Software, Ltd.
560 Rochester Street, Suite 400
Ottawa, Ont. K1S-5K2
613-594-3026

Software operates under MS-Windows; supports printing of barcodes.

Bar code system
Worthington Data Solutions
417-A Ingalls Street
Santa Cruz, CA 95060
800-345-4220

Produces hand-held microcomputers, bar code readers, and labelling software.
Price: $279 to $849

Sharp JX-450 Professional Color Scanner
Sharp Electronics
Sharp Plaza
Mahwah, NJ 07430
201 529-9500

Produces flatbed color scanner that supports 30 to 300 dpi image resolution.
Price: $6,995

Howtek Scanmaster
Howtek
21 Park Avenue
Hudson, NH 03051
603-882-5200

Produces flatbed color scanner that supports 20 to 300 dpi image resolution.
Price: $6,995

New Image MacScanColor
New Image Technology
9701 Philadelphia Court
Lanham, MD 20706
301-731-2000

Produces flatbed color scanner that supports 30 to 300 dpi image resolution.
Price: $7,590

ScanJet Plus
Hewlett-Packard Company
700 71st Avenue
Greeley, CO 80634
303-350-4000

This manufacturer's 8-bit grayscale scanner interpolation capability allows image resolution up to 1500 dpi.
Price: $2,250

PC Scan 1000
Dest Corporation
1201 Cadillac Court
Milpitas, CA 95035
408-946-7100

Produces a 4-bit scanner that supports 16 gray tones. Offers good text-extraction capabilities.
Price: $1,750

DS-2000 and DS-3000 Scanner
Chinon America, Inc.
660 Maple Avenue
Torrance, CA 90503
800-441-0222

Produces black and white and grayscale scanners with 200 and 300 dpi resolution.

ScanMan
Logitech
800-552-8885

Manufacturers hand-held grayscale scanner that supports 100 to 400 dpi image resolution.
Price: $339 to $399

PC1000
Hearsay, Inc.
1825 74th Street
Brooklyn, NY 11204
718-259-4934

A combination speech synthesis and voice recognition system that allows software commands to be given verbally.

Speech Thing
Covox, Inc.
675 Conger Street
Eugene, OR 97402
503-342-1271

This 8-bit speech synthesis and voice recognition system is compatible with most DOS software.
Price: $79.95

Data acquisition hardware and software
Dataq Instruments, Inc.
825 Sweitzer Avenue
Akron, Ohio 44311
800-553-9006

IBM-compatible data acquisition hardware and software.

Data acquisition and control
Alpha Products
242-B West Avenue
Darien, CT 06820
203-656-1806

Produces microcomputer hardware for process control, robotics, data acquisition, and sensing.
Price: $12 to $300

Data acquisition, control, and analysis
National Instruments
12109 Technology Boulevard
Austin, TX 78727-6204
512-250-9119

Produces IEEE-488 data acquisition and control hardware, and LabView and LabWindows software for PCs, Macs, and VAX systems.
Price: $30 to $10,000

Output Devices

Polaroid PalettePlus
Polaroid Corporation
575 Technology Square
Cambridge, MA 02139
800-225-1618

Easy-to-use 35mm film recorder for making 35mm slides using microcomputer output.
Price: $2,999

Matrix ProColor
Matrix Instruments Inc.
1 Ramland Road
Orangeburg, NY 10962
800-852-8533

High quality digital film recorder for making 35mm slides using microcomputer output.
Price: $7,990 to $8,490

Montage FR1
Presentation Technologies
743 North Pastoria Avenue
Sunnyvale, CA 94086
800-345-7050

A film recorder that operates in Apple Macintosh and DOS environments.
Price: $5,995 to $6,995

ColorSpace II
MASS Microsystems
550 Del Rey Avenue
Sunnyvale, CA 94086
800-522-7979

Video frame-grabbing, genlocking, and compression hardware for Macintosh computers.
Price: $1,995 to $2,995

Frame grabber
Data Translation Inc.
100 Locke Drive
Marlboro, MA 01752-1192
508-481-3700

All-purpose video frame grabber for IBM-AT compatible PCs.
Price: $1,795

ViewFrame II+2
nView
11835 Canon Boulevard
Newport News, VA 23606
804-873-1354

LCD display device that allows projection of computer displays using overhead projector. IBM and Macintosh compatible.

Communications Hardware

The Complete Communicator
The Complete PC
521 Cottonwood Drive
Milpitas, CA 95035
408-434-0145

Add-on board that combines modem fAX, and voice mail capabilities for IBM-compatible PCs
Price: $899

The Watson
Natural MicroSystems Corporation
8 Erie Drive
Natick, MA 01760-1313
800-533-6120

Automated telephone answering and voice mail system; runs in background on IBM-compatible PCs.
Price: $199

Operating Systems

Concurrent DOS 386
Digital Research Inc.
Box DRI
Monterey, CA 93942
408-646-6464

A multitasking and multiuser alternative operating system related to CP/M.
Price: $395

DESQview 386
Quarterdeck Office Systems
150 Pico Boulevard
Santa Monica, CA 90405
213-392-9851

A text-based multitasking DOS enhancer that is easy to install and operate.
Price: $189

Microsoft Windows/386
Microsoft Corporation
16011 N.E. 36th Way Box 97017
Redmond, WA 98073
206-882-8080

A multitasking DOS enhancer best for applications such as *Microsoft Excel* and *Aldus PageMaker*.
Price: $195

VM/386
Intelligent Graphics Corporation
4800 Great America Pkwy.
Santa Clara, CA 95054
408-986-8373

A nonwindowing multitasking DOS enhancer that creates up to 4 virtual machines; highly customizable.
Price: $245

General office automation software

Wingz
Informix Software
16011 College Blvd.
Lenexa, KS
913-492-3800

A powerful spreadsheet program and applications development environment for the Macintosh; includes Hyperscript language.
Price: $399

Utilities

Sideways
Funk Software
222 Third Street
Cambridge, MA o2142
617-497-6339

Utility for printing oversized output (e.g., wide spreadsheets) sideways.
Price: $39

FormWorx
FormWorx Corporation
Reservoir Place, 1601 Trapelo Road
Waltham, MA 02154
800-992-0085

Form-filling software for IBM-compatible PCs.
Price: $81

Horizon
FormMaker Software Inc.
57 S. Schillinger Road
Mobile, AL 36608
800-888-8423

Windows-based electronic form design software provides easy editing and WYSIWYG preview.

JetForm
Indigo Software Limited
560 Rochester Street
Ottawa, Canada K1S 5K2
800-267-9976

Electronic form design software.

Formfiller
Bloc Publishing
800 SW 37th Avenue, Suite 765
Coral Gables, FL 33134
800-888-2562

Software for automating filling in existing forms using microcomputer output.
Price: $149

XTree
XTree Company
4330 Santa Fe Road
San Luis Obispo, CA 93401
800-634-5545

Disk management software that graphically displays directory tree at a glance.
Price: $69

ViewLink
Traveling Software
18702 N. Creek Parkway
Bothell, WA 98011
800-343-8080

Associative access manager links all existing programs and data for instant information access and organization.
Price: $89

Lotus Magellan
Lotus Development Corp.
55 Cambridge Parkway
Cambridge, MA 02142
617-577-8500

Hard disk utility that provides file viewing and searching across directory boundaries.
Price: $195

Norton Utilities
Peter Norton Computing
2210 Wilshire Boulevard, Suite 186
Santa Monica, CA 90403
213-319-2000

Hard disk maintenance and rescue utilities.
Price: $150

Mace Utilities Gold
Paul Mace Software, Inc.
400 Williamson Way
Ashland, OR 97520
503-488-2322

Hard disk maintenance and rescue utilities.
Price: $149

Disk Technician Plus
Prime Solutions, Inc.
1940 Garnet Avenue
San Diego, CA 92109
619-274-5000

Hard disk maintenance and rescue utility.
Price: $79

SpinRite
Gibson Research Corp.
22991 La Cadena
Laguna Hills, CA 92653
714-830-2200

Hard disk optimizing and diagnosis software.
Price: $59

AXE
SEA
21 New Street
Wayne, NJ 07470
201-473-5153

Utility compresses size of .COM and .EXE files as much as 60 percent.
Price: $50

System Sleuth
DTG
23704-5 El Toro Road, Suite 348
El Toro, CA 92630
213-987-2000

System diagnosis and repair utility tests memory, peripherals, disks, I/O, processors, displays and more.
Price: $149

CADD Software

AutoCAD
AutoDesk Inc.
2320 Marinship Way
Sausalito, CA 94965
415-332-2344

A flexible, powerful, full-featured CADD package that offers macros and a programming language.
Price: $2,850

Generic CADD
Generic Software, Inc.
8763 148th Avenue NE
Redmond, WA 98052
800-228-3601

A powerful production drafting program at a relatively low price.
Price: $99.95 to $500

Drafix 1 Plus
Foresight Resources Corporation
932 Massachusetts Ave
Lawrence, KS 66044
913-841-1121

This is a fast, easy-to-use CADD, but it does not have macro or programming language.
Price: $295

AutoSketch
AutoDesk, Inc.
2320 Marinship Way
Sausalito, CA 94965
415-332-2344

An inexpensive, easy-to-use package that is best for educational purposes or casual drafting.
Price: $79.95

Cadkey 1
Cadkey Div., Micro Control Systems, Inc.
27 Hartford Tpk.
Vernon, CT 06066

A full-featured, 3-D CADD package.
Price: $395

EasyCad
Evolution Computing
487 South 48th Street
Tempe, AZ 85281
602-967-8633

Very easy to use, with many sophisticated features including programming language and macros.
Price: $169.95

Special-purpose software

SoftPC
Insignia Solutions
787 Lucerne Drive
Sunnyvale, CA 94086
408-522-7600

Application program that emulates DOS on a Macintosh computer. Allows PC and Macintosh to share programs and files.
Price: $595

MacLink Plus
Data Viz
35 Corporate Drive
Trumball, CT 06611
203-268-0030

Macintosh program allows file transfer between Macs and PCs.
Price: $195

Lap-Link Mac
Traveling Software
19310 N. Creek Pkwy
Bothell, WA 98010
206-483-8088

PC-based program allows file transfer between PCs and Macs.
Price: $139.95

PC to Mac and Back
Dilithium Press
8285 SW Nimbus #151
Portland, OR 97005
503-243-3313

PC-to-Mac file transfer utility.
Price: $149

pcAnywhere III
Dynamic Microprocessor Associates
60 E. 42nd Street
New York, NY 10165
212-687-7115

Communications package allows a microcomputer to be controlled remotely by a PC or Macintosh.
Price: $145

SuperProject
Computer Associates
1240 McKay Dr.
San Jose, CA 95131
800-531-5236

Flexible project management software.
Price: $409

TimeLine
Symantec Corporation
10201 TORRE Ave.
Cupertino, CA 95014
408-253-9600

Project management software.
Price: $349

Project Scheduler 4
Scitor Corp.
250 Lincoln Centre Drive
Foster City, CA 94404
415-570-7700

Project scheduler with graphical interface.

File Encrypt
Wisdom Software
P.O. Box 460310
San Francisco, CA 94146
800-456-7276

File encryption data security software.
Price: $69.95

MailSafe
RSA Data Security Inc.
10 Twin Dolphin Drive
Redwood City, CA 94065
415-595-8782

Key-based data transmission security software; uses public and private keys.
Price: $250

Watchdog
Fischer International Systems
4073 Merchantile Avenue
Naples, FL 33942
813-643-1500

File and system protection software.
Price: $295

CPU Lock II
MPPI, Ltd.
2200 Lehigh Avenue
Glenview, IL 60025
312-998-8401

File and system protection software.
Price: $69.95

Secret Disk II
Lattice, Inc.
2500 South Highland Ave.
Lombard, IL 60148
312-916-1600

File encryption security software.
Price: $79

Certus
Foundation Ware
2135 Renrock
Cleveland, OH 44118
216-932-7717

Virus protection, data and system security, and hard disk utility software.
Price: $189

Dr. Panda Utilities
Panda Systems
801 Wilson Road
Wilmington, DE 19803
302-764-4722

Effective system for monitoring disk and system activity; includes program to prevent Pakistani Brain virus.
Price: $79.95

Flu_Shot+
Software Concepts Design
594 Third Avenue
New York, NY 10016
212-889-6431

Full-featured multi-option virus protection program.
Price: $10

Mace Vaccine
Paul Mace Software, Inc.
400 Williamson Way
Ashland, OR 97520
503-488-2322

Easy-to-use software prevents unauthorized alteration of system files; monitors for presence of viruses.
Price: $20

Vaccine
WorldWide Data Corp.
New York, NY 10004
212-422-4100

Virus protection software.
Price: $129

C-4
Interpath
4423 Cheeney Street
Santa Clara, CA 95054
408-988-3832

Virus protection software.
Price: $39.95

Virusafe
COMNETCO, Inc.
29 Olcott Square
Bernardsville, NJ 07924
201-953-0322

Virus protection software.
Price: $150

DiscWatcher
RG Software Systems
2300 Computer Ave.
Willow Grove, PA 19090
215-659-5300

Virus protection software; detects attempts to modify .EXE or .COM files.
Price: $99.95

Tickler/2
Enyart Development Corp.
7000 East 70th Avenue
Commerce City, CO 80022
303-286-8686

OS/2-based personal scheduler that enables automation of e-mail, spreadsheet, and database functions on microcomputers.
Price: $80

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